223rd Annual AAS Meeting
Washington, DC – January, 2014
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90 – HAD I: Origin of Structure and the Expanding Universe

Special Session – Baltimore 5 – 05 Jan 2014 01:30 pm to 03:30 pm

When Hot Big Bang cosmology became widely accepted from the 1960s theorists realised that an explanation of how structure arises in the universe was a complex intellectual puzzle. Speakers in this session will explore how aspects of the problem of structure formation developed in the last century. Speakers will explain how the problem of origin - the "why is there something rather than nothing?" question slowly dawned. Speakers will explain why expansion models of the universe were only slowly accepted. New scholarship sheds light on the exchanges between Einstein and Hubble. A new timeline will be presented of events in 1948 concerning the thermal radiation associated with a hot expansion. The session concludes with an assessment of Beatrice Tinsley's contribution to derailing the famous "search for two numbers" that would define the evolution of the universe.

90.01 – NOR YET THE LAST TO LAY THE OLD ASIDE: Structuring the Something

Virginia L. Trimble[1]

1. UC, Irvine, Irvine, CA, United States.

Once we agree that the Universe is full of stuff, obvious follow-up questions are how is it arranged and why that way rather than some other? For many cultures, the distributing has been part and parcel of the creation. The modern view shoves baryogenesis, leptogenesis, WIMP- genesis, and all very far back in time, but builds up structure continuously, using not-very-special initial conditions and gravity (plus perhaps other forces) to develop what we see today. In between come some remarkable constructs, including Thomas Wright's hierarchy, Descartes's Voronoi tesselation of whirlpools in the aether, Alfred Russel Wallace's (yes, the evolution guy) "Goldilocks" location for the solar system, Cornelis Easton's off-center spiral arms, and the Kapteyn Universe. The talk will explore some of these and others, why the proposers thought they were likely, and the supporting entities they were required to abandon—luminiferous aether, solar system centrality, transparent space, and all. Dark stars and dark matter, under those names, were part of the inventory from early interpretations of Beta Lyrae, through the writings of A.M. Clerke, to 1922 papers by Kapyteyn and Jeans.

90.02 – A One Galaxy Universe and the Shift to Modern Cosmology

Robert W. Smith[1]

1. Univ. of Alberta, Edmonton, AB, Canada.

It was generally believed in 1900 that the visible universe consisted of our own galactic system. Some astronomers reckoned other galaxies might exist, but such external stellar systems had not been sighted in even the most powerful telescopes. In this paper I will examine these views and then explore how and why they fell from favor such that a recognisably modern cosmology had begun to emerge within another two decades.

90.03 – REDSHIFTS AND THE EXPANDING UNIVERSE - PARADIGM SHIFT OR SLOW DAWNING?

Cormac O Raifeartaigh[1]

1. Waterford Institute of Technology, Waterford, Ireland, Ireland.

The observation by Edwin Hubble of a linear relation between the redshift of the spiral nebulae and their radial distance marked one of the great discoveries of 20th century astronomy. This paper examines how the finding was interpreted as possible evidence for a universe of expanding radius by a number of theoreticians, but not astronomers. A brief review of the cosmic models of theoreticians such as Lemaître, Eddington, Einstein, de Sitter and Tolman is given, contrasting their different views of issues such as spatial curvature, the cosmological constant, the singularity and the formation of structure. It is argued that the concept of an expanding universe was not fully accepted for many years, and is best seen as the slow dawning of an idea rather than an abrupt Kuhnian paradigm shift.

90.04 – Dismantling Hubble's Legacy?

Michael J. Way[1, 2]

1. NASA/Goddard Institute for Space Studies, New York, NY, United States. 2. Department of Physics and Astronomy, Uppsala, Sweden.

Edwin Hubble is famous for a number of discoveries that are well known to amateur and professional astronomers, students and even the general public. The origins of three of the most well-known discoveries are examined: The distances to nearby spiral nebulae, the classification of extragalactic-nebulae and the Hubble constant. In the case of the first two a great deal of supporting evidence was already in place, but little credit was given. The Hubble Constant had already been estimated in 1927 by Georges Lemaitre with roughly the same value that Hubble obtained in 1929 using redshifts provided mostly by Vesto M. Slipher. These earlier estimates were not adopted or were forgotten by the astronomical community for complex scientific, sociological and psychological reasons.

90.05 – What happened in 1948?

P. J. Peebles[1]

1. Princeton University, Princeton, NJ, United States.

The idea that the universe is filled with the sea of thermal radiation now termed the Cosmic Microwave Background was first discussed in eleven publications in the year 1948 by Alpher, Herman, and Gamow. Precision measurements of this radiation are a central part of the evidence establishing the relativistic hot Big Bang theory of the expanding universe. The eleven 1948 papers offer a fascinating illustration of the exploration of a new line of research, and the confusion that can attend it. That includes a common misunderstanding of the considerations that led to the idea of this thermal radiation.

90.06 – How Beatrice Tinsley Destroyed Sandage's Quest for a Standard Candle

Simon Mitton[1]

1. University of Cambridge, Cambridge, United Kingdom.

The goal of cosmology and most extragalactic optical astronomy during the heroic period spanning the half century from Hubble to Sandage (1920s – 1970s) was a search for two numbers, the Hubble constant and the deceleration parameter. Standard candles were needed to establish the measure of the universe. In 1968, Beatrice Tinsley, then a postdoctoral fellow in the astronomy department of the University of Texas at Austin showed that the great enterprise at Palomar of calibrating the galaxies was in need of major revision. At the 132nd AAS Meeting (June 1970, Boulder, Colorado) she presented a paper on galactic evolution on the magnitude-redshift relation. In her Abstract she boldly wrote: "My present conclusion is opposite to that reached by most cosmologists." In fact her claims caused great consternation among cosmologists. In 1972 she published eight papers on the evolution of galaxies, and the effects of that evolution for observational cosmology and the origin of structure.

91 – HAD II: From Barnard's Star to the Kepler Mission: Searching for Low Mass Companions to Stars

Special Session – Baltimore 5 – 05 Jan 2014 04:00 pm to 06:00 pm

One of the signal advances in astronomy in the last 25 years has been the discovery of extrasolar planets. Speakers in this session will examine the role of applying new technologies, hardware and software, scientific and cultural, to the search for planets in the universe. Speakers will identify what the limits of detection have been over the past century, and how these limits have been extended to the point where humanity seems now on the verge of actually finding habitable abodes of life circling other stars. Speakers who have been participants in the process will discuss their strategies and modes of operation, and what they feel are the key artifacts of the material heritage of the process that should be preserved to better record and appreciate this stage in the search for life in the universe. Speakers include Geoff Marcy, David Latham, Gordon Walker, Bill Borucki, Tim Brown, and Edward Dunham.

91.01 – Hydrogen Fluoride: an unexpected calalyst in the search for extra-solar planets

Gordon A. Walker[1]
1. , Victoria, BC, Canada.

In the 1970s we developed low light level digital TV systems at UBC for the DAO 1.2-m telescope coudé spectrograph. John Glaspey eliminated reading-beam jitter using telluric water vapor lines as fiducials. Later, when we switched to solid state diode arrays, I suggested to Bruce Campbell that we could look for extra-solar planets using telluric lines to eliminate RV errors induced by irregular slit illumination. He went a step further by introducing a deployable absorption cell of hot HF gas. In December 1978 he and I demonstrated that an RV precision ~10 m/s was possible from observations of the Sun! Sufficient precision to detect the reflex acceleration of a solar-type star accompanied by a Jupiter. Bruce moved to CFHT in 1979 where the coudé spectrograph was a replica of that at DAO. He built an HF cell and gas handling system and we were granted some 6 to 8 nights per year. Modeling the line spread function proved critical in the reductions while, at the telescope, isolation of the telescope exit pupil and estimation of the epoch of the weighted mean exposure time were key. The program lasted some 12 years with, initially, little to show by way of results other than demonstrating the technique worked and so it attracted little interest but ample skepticism.

91.02 – The Unseen Companion of HD 114762

David W. Latham[1]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.

I have told the story of the discovery of the unseen companion of HD114762 (Latham et al. 1989, Nature, 389, 38-40) in a recent publication (Latham 2012, New Astronomy Reviews 56, 16-18). The discovery was enabled by a happy combination of some thinking outside the box by Tsevi Mazeh at Tel Aviv University and the development of new technology for measuring stellar spectra at the Harvard-Smithsonian Center for Astrophysics. Tsevi's unconventional idea was that giant exoplanets might be found much closer to their host stars than Jupiter and Saturn are to the Sun, well inside the snow line. Our instrument was a high-resolution echelle spectrograph optimized for measuring radial velocities of stars similar to the Sun. The key technological developments were an intensified Reticon photon-counting detector under computer control combined with sophisticated analysis of the digital spectra. The detector signal-processing electronics eliminated persistence, which had plagued other intensified systems. This allowed bright Th-Ar calibration exposures before and after every stellar observation, which in turn enabled careful correction for spectrograph drifts. We built three of these systems for telescopes in Massachusetts and Arizona and christened them the "CfA Digital Speedometers". The discovery of HD 114762-b was serendipitous, but not accidental.

91.03 – Technology Enabling the First 100 Exoplanets

Geoffrey W. Marcy[1]
1. UC, Berkeley, Berkeley, CA, United States.

The discoveries of the first 100 exoplanets by precise radial velocities in the late 1990's at Lick Observatory and Observatoire de Haute-Provence were enabled by several technological advances and a cultural one. A key ingredient was a cross-dispersed echelle spectrometer at a stable, coude focus, with a CCD detector, offering high spectral resolution, large wavelength coverage, and a linear response to photons. A second ingredient was a computer capable of storing the megabyte images from such spectrometers and analyzing them for Doppler shifts. Both Lick and OHP depended on these advents. A third ingredient was a stable wavelength calibration. Here, two technologies emerged independently, with iodine gas employed by Marcy's group (used first by solar physicists doing helioseismology) and simultaneous thorium-argon spectra (enabled by fiber optics) used by Mayor's group. A final ingredient was a new culture emerging in the 1990's of forward-modeling of spectra on computers, enabled by the well-behaved photon noise of CCDs, giving Poisson errors amenable to rigorous statistical algorithms for measuring millipixel Doppler shifts. The prospect of detecting the 12 meter/sec reflex velocity (1/100 pixel) of a Jupiter-like planet was considered impossible, except to a few who asked, "What actually limits

Doppler precision?". Inspired insights were provided by Robert Howard, Paul Schechter, Bruce Campbell, and Gordon Walker, leading to the first 100 exoplanets.

91.04 – Barriers to the Development of the Kepler Mission

William J. Borucki[1], Natalie M. Batalha[1], Edward W. Dunham[3], Jon M. Jenkins[2]
1. NASA Ames Research Center, Moffett Field, CA, United States. 2. SETI Institute, Mountain View, CA, United States. 3. Lowell Observatory, Flagstaff, AZ, United States.
Contributing teams: Kepler Science Team

No one had ever proposed nor flown a spacecraft mission that could do automated photometry of many thousands of stars simultaneously with the 10 ppm photometric precision necessary to detect the transits of Earth-size planets. Consequently, several barriers needed to be overcome before the Kepler Mission concept was accepted by the Discovery Program review panel. To overcome these barriers it was necessary to; 1) demonstrate that an appropriate combination of detectors and data analysis techniques was available that had the precision necessary to detect transits of Earth-size planets, 2) prove that the variability of solar-like stars was likely to be sufficiently low that SNR of transits from Earth-size planets could be detected with high reliability, 3) demonstrate the automated observations of thousands of stars simultaneously and the automated analysis of the observations, 4) develop a lab test facility to demonstrate the 10ppm photometric precision necessary to find Earth-sized planets orbiting solar-like stars and do it in the presence of the noise expected from on-orbit operation including thermal variations, the presence of nearby stars, and the impact of energetic particles, 5) form a team of experienced, technically qualified people who agreed that the technique would work and that they would support the mission development, operation, and the analysis of the results. The approaches used to overcome these barriers will be presented.

91.05 – The Discovery of Extrasolar Planets via Transits

Edward W. Dunham[1], William J. Borucki[2], Jon M. Jenkins[3], Natalie M. Batalha[2], Douglas A. Caldwell[3], Georgi Mandushev[1]
1. Lowell Obs., Flagstaff, AZ, United States. 2. NASA Ames, Moffett Field, CA, United States. 3. SETI Institute, Mountain View, CA, United States.

The goal of detecting extrasolar planets has been part of human thought for many centuries and several plausible approaches for detecting them have been discussed for many decades. At this point in history the two most successful approaches have been the reflex radial velocity and transit approaches. These each have the additional merit of corroborating a discovery by the other approach, at least in some cases, thereby producing very convincing detections of objects that can't be seen. In the transit detection realm the key enabling technical factors were development of: - high quality large area electronic detectors - practical fast optics with wide fields of view - automated telescope systems - analysis algorithms to correct for inadequacies in the instrumentation - computing capability sufficient to cope with all of this This part of the equation is relatively straightforward. The more important part is subliminal, namely what went on in the minds of the proponents and detractors of the transit approach as events unfolded. Three major paradigm shifts had to happen. First, we had to come to understand that not all solar systems look like ours. The motivating effect of the hot Jupiter class of planet was profound. Second, the fact that CCD detectors can be much more stable than anybody imagined had to be understood. Finally, the ability of analysis methods to correct the data sufficiently well for the differential photometry task at hand had to be understood by proponents and detractors alike. The problem of capturing this changing mind-set in a collection of artifacts is a difficult one but is essential for a proper presentation of this bit of history.

91.06 – Adapting Low-Tech Gear to Exoplanet Discovery

Timothy M. Brown[1, 2]
1. Las Cumbres Global Telescope Network, Inc., Goleta, CA, United States. 2. CU/CASA, Boulder, CO, United States.

The discovery of 51 Peg b by Mayor and Queloz revealed (among other things) that discovering extrasolar planets, though certainly difficult, was not as hard as professional astronomers had previously thought. At the same time, the astronomical equipment available to amateurs -- including optics, mountings, and CCD detectors -- had become quite capable. This combination of factors led to successful exoplanet programs that leaned heavily on amateur-grade hardware, seeking faster development times and lower costs than were possible for traditional no-compromises astronomical instrument programs. I will describe two of these in which I played a role: the AFOE (Advanced Fiber Optic Echelle) spectrograph, and the STellar Astrophysics and Research on Exoplanets (STARE) transit-search wide-field imager.

100 – Welcome Address
Plenary Session – Potomac Ballroom A – 06 Jan 2014 08:00 am to 08:30 am

101 – Kavli Foundation Lecture: The Hubble Deep Field and its Legacy

Plenary Session – Potomac Ballroom A – 06 Jan 2014 08:30 am to 09:20 am

101.01 – The Hubble Deep Field and its Legacy

Robert E. Williams[1]

1. STScI, Baltimore, MD, United States.

Although deep images of distant galaxies were hardly a novel concept at the time, various aspects of the Hubble Deep Field resulted in its influence on subsequent studies of high redshift objects and on the culture in which large projects are carried out on unique facilities. The sensitivity, spatial resolution, and low background of HST were essential in making the HDF a success in its imaging of galaxy evolution from after the epoch of reionization to the present time. Subsequent deep fields and follow up studies on HST and other facilities have produced a number of results important to our understanding of galaxy evolution. Among these are: establishing the credibility of photometric redshifts as a foundation for extragalactic research; determination of the rate of star formation over cosmological time; producing early, reliable maps of dark matter; providing essential SNe data that revealed dark energy; resolving the X-ray background; enabling the evolution of galaxy luminosity functions to be determined; and yielding detailed gravitational lensing maps that identify the locations of magnified images of z>10 objects around clusters of galaxies. Undertaken using HST Director's Discretionary time the HDF set a precedent by providing unique non-proprietary observational data to the community in addition to a fully reduced dataset virtually immediately after the observations were taken. Collaborative follow up studies on other facilities, e.g., Keck spectroscopy, Chandra X-ray imaging, etc., that were important to the interpretation of the HDF images were arranged even before the HDF observations were taken in order to facilitate analysis of the joint data. These collaborative programs were as essential to the success of the HDF as the HST images themselves.

145 – New Science from the CLASH/CANDELS Multi-Cycle Treasury Programs Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

145.01 – Optical And Near-infrared Variability Among Distant Galactic Nuclei Of The CANDELS EGS Field

Norman A. Grogin[1], Tomas Dahlen[1], Jennifer Donley[2], Anton M. Koekemoer[1], Mara Salvato[3]
1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Los Alamos National Laboratory, Los Alamos, NM, United States. 3. Max Planck Institute for Extraterrestrial Physics, Garching, Germany.
Contributing teams: The CANDELS Collaboration

The CANDELS HST Multi-cycle Treasury Program completed its observations of the EGS field in May 2013. The coverage comprises WFC3/IR exposures in J-band and H-band across a contiguous 200 square arcminutes, and coordinated parallel ACS/WFC exposures in V-band and I-band across a contiguous 270 square arcminutes that largely overlaps the WFC3/IR coverage. These observations were split between two epochs with 52-day spacing for the primary purpose of high-redshift supernovae (SNe) detection and follow-up. However, this combination of sensitivity, high resolution, and time spacing is also well-suited to detect optical and near-infrared variability ("ONIV") among moderate- to high-redshift galaxy nuclei (H<25AB mag; I<26AB mag). These data are sensitive to rest-frame variability time-scales of up to several weeks, and in combination with the original EGS ACS imaging from 2004, to time-scales of up to several years in the V- and I-bands. The overwhelming majority of these variable galaxy nuclei will be AGN; the small fraction arising from SNe have already been meticulously culled by the CANDELS high-redshift SNe search effort. These ONIV galaxy nuclei potentially represent a significant addition to the census of distant lower-luminosity AGN subject to multi-wavelength scrutiny with CANDELS. We present the preliminary results of our EGS variability analysis, including a comparison of the HST ONIVs with the known AGN candidates in the field from deep Spitzer and Chandra imaging, and from extensive ground-based optical spectroscopy as well as HST IR-grism spectroscopy. We also assess the redshift distribution of the ONIVs from both spectroscopy and from robust SED-fitting incorporating ancillary deep ground-based imaging along with the CANDELS VIJH photometry. We compare these results with our prior variability analysis of the similarly-observed CANDELS UDS field from 2011 and CANDELS COSMOS field from 2012.

145.02 – Automated PSF Modeling for Hubble Images

Timothy S. Hamilton[1]
1. Shawnee State Univ., Portsmouth, OH, United States.

Two techniques have commonly been used to model the Point Spread Function (PSF) of Hubble images: a natural PSF from observed stars, and an artificial PSF from the TinyTim software. PSF models need to be matched in color, subpixel centering, and focus, which takes a good deal of time and effort and slows down work in large surveys. I present the public release of software for automating an artificial PSF fit. This program needs very little user interaction and is designed to be used in anything from one PSF in a single image up to many in a large-scale survey. Applications to active galaxies are shown from the CANDELS survey, where the PSF is subtracted to show the host galaxy.

145.03 – Red CANDELS: Physical Properties of IRAC Sources Undetected in the F160W Band in CANDELS Fields

Mauro Stefanon[1], Haojing Yan[1]
1. , Columbia, MO, United States.
Contributing teams: CANDELS

The recent increase in depth, spatial and wavelength coverage of extragalactic surveys has put together a more comprehensive picture of the physical processes that governed the formation and evolution of galaxies in the last 12 billion years of cosmic history. However, potential biases in the detection of galaxies can affect even the deepest surveys. For example, starting at z~3, the 4000A break, a fingerprint of old galaxies, is shifted to even redder wavelengths than the F160W filter, which could make the detection of such objects severely incomplete. We present preliminary results from a systematic search for sources in IRAC images that are not detected in the F160W CANDELS maps (a.k.a. "H-dropout") over the ~650 sq. arcmin of the GOODS, COSMOS, UDS and EGS fields. Using the ancillary data spanning from UV to mid-IR, we separate the contributions from galaxies, cool stars and active galactic nuclei in the sample, and study the stellar population parameters and their star-formation histories.

145.04 – Unsupervised Machine Learning to Track Galaxy Morphological Evolution in CANDELS

Michael Peth[1], Jennifer M. Lotz[2], Peter E. Freeman[3], Conor McPartland[4, 2]
1. Johns Hopkins University, Baltimore, MD, United States. 2. STSci, Baltimore, MD, United States. 3. Carnegie Mellon University, Pittsburgh, PA, United States. 4. University of Hawai'i, Honolulu, HI, United States.
Contributing teams: the CANDELS Collaboration

We use unsupervised machine learning techniques to study the evolution of galaxy morphology at 0 < z < 3 in the CANDELS fields. We use principal component analysis and diffusion mapping to study the correlations between concentration (C), Gini coefficient (G), Asymmetry (A), the second-order moment of brightest 20% light (M_20), and three new statistics, Multi mode (M), Intensity (I) and Deviation (D). We measure these morphology statistics in 4 different HST wavebands: F160W (H), F125W, F814W and F606W. This allows us to consistently measure a single rest-frame passband across the redshift range. We discuss the implications for the evolution of the Hubble sequence and galaxy mergers over the last 10 billion years.

145.05 – To Stack or Not to Stack: Physical Properties of Lyman-α Emitting Galaxies at z = 2.1

Hannah Bish[1], Carlos J. Vargas[1, 2], Viviana Acquaviva[3], Eric J. Gawiser[1], Steven L. Finkelstein[4], Robin Ciardullo[5]
1. Rutgers, The State University of New Jersey, Metuchen, NJ, United States. 2. New Mexico State University, Las Cruces, NM, United States. 3. New York City College of Technology, Brooklyn, NY, United States. 4. The University of Texas at Austin, Austin, TX, United States. 5. The Pennsylvania State University, University Park, PA, United States.
Contributing teams: the MUSYC collaboration, the CANDELS collaboration

We present the first study of Spectral Energy Distributions (SEDs) of individual Lyman-α Emitting (LAE) galaxies at z = 2.1 by Vargas et al. (2013, ArXiv:1309.6341). This sample of 20 LAEs was discovered by the MUSYC collaboration (Guaita et al. 2010) and matched with counterparts in the CANDELS GOODS-S multi-wavelength catalog (Grogin et al. 2011; Koekemoer et al. 2011), which offers deep enough photometry to enable the study of individual LAE SEDs. SpeedyMC, a Markov Chain Monte Carlo SED fitting code (Acquaviva et al. 2012), was used to constrain the physical properties of these objects including stellar mass, age, and dust content. Individual LAEs at z = 2.1 are found to have stellar masses ranging from 2.3×10^7 to 8.5×10^9 M_sun with a median of 2.8×10^8 M_sun, ages ranging from 4 to 473 Myr with a median of 94 Myr, and dust reddening, E(B-V), ranging from 0.02 to 0.24 with a median of 0.12. Our LAEs lie systematically above the SFR-stellar mass "main sequence," with an increased upward scatter at low mass that may be due to ongoing bursts of star formation. Several stacking methods typically used to study LAE SEDs at low signal-to-noise were also used, and the results compared to those of the individual SED analysis. The SED parameters of the flux stacks match the average and median values of the individual objects, with the flux-scaled median stack performing the best.

145.06 – Evolution of Visually Disturbed Galaxies from 0.6<z<2.5 in the CANDELS UDS Field

Joshua Cook[1], Daniel H. McIntosh[1], Jeyhan S. Kartaltepe[2], Anton M. Koekemoer[3], Jennifer M. Lotz[3], Stijn Wuyts[4], Eric F. Bell[5], Christopher Conselice[6]
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Contributing teams: The CANDELS Collaboration

The early assembly of massive galaxies is predicted to heavily impact galaxy morphology and structure. As such, the evolution of visually disturbed systems may help constrain the relative importance of different processes such as merging and violent disk instabilities, which is largely debated especially at redshifts above z=1. Using a new comprehensive catalog of visual classifications based on the HST/WFC3 imaging from the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS), we study the population of visually disturbed galaxies with Mstar > 10^10 Msun over a wide redshift range (0.6 < z < 2.5) in the Ultra Deep Survey (UDS) field. We further divide this sample into three interpretive bins: merging, interacting (in a pair), and non-merging (isolated). We examine Gini-M20 and rest-frame UVJ color-color distributions as a function of redshift. We find that morphologically disturbed galaxies are star-forming at all redshifts, and tend to be less centrally-concentrated compared with a control sample of smooth disk and/or spheroidal galaxies. We find a significant drop in the mass fraction of galaxies with a smooth appearance down to ~50% at z~2, accompanied by a modest increase in the disturbed fraction with redshift, but we tentatively conclude that most of the rise appears unrelated to merging. With the remaining CANDELS fields, we will quadruple our sample size and better constrain the merging evolution using deep/shallow comparisons for a representative subset.

145.07 – Probing the Reionization Epoch At Redshift ~8

Vithal Tilvi[1], Steven L. Finkelstein[2], Casey J. Papovich[1], Mark Dickinson[3], Mimi Song[2], Henry C. Ferguson[4], Anton M. Koekemoer[4], Mauro Giavalisco[5]
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Evolution of Lyman-alpha line provides an unique probe of the neutral fraction of hydrogen in the Intergalactic medium and hence the reionization history of the universe. Here we present results from extremely deep spectroscopic observations of redshift ~8 galaxies, obtained from the MOSFIRE instrument. We find that the observed Lyman-alpha fraction at z~8 is at least a factor of three lower compared with the z~6 Lyman-alpha fraction. This suggests that the universe is significantly neutral at z~8 and the reionization is not complete until at this redshift. In addition, we test for two different scenarios of reionization : Patchy vs Smooth. We find that in order to distinguish between these two models we require a larger sample of spectroscopic observations-- even non-detections will be able to distinguish between the two models.

145.08 – A progenitor of today's typical galaxy clusters at z=1.84

Simona Mei[1], Claudia Scarlata[2], Laura Pentericci[3], Jeffrey Newman[4], Harry I. Teplitz[5], Benjamin J. Weiner[6], Matthew Ashby[7], Marco Castellano[3], Christopher Conselice[8], Steven L. Finkelstein[9], Audrey Galametz[3], Anton M. Koekemoer[10], Ray A. Lucas[10], Marc Rafelski[5]
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Contributing teams: CANDELS team

We present the discovery of a proto-cluster at z=1.84 in the Hubble Ultra Deep Field. The lack of X–ray emission and the member velocity dispersion permit us to estimate an upper mass limit of 1 3 × 1014M™. We also observe the lack of a red sequence, with only a few passive galaxies with photometric redshifts consistent with the proto–cluster redshift. We discuss the properties of these galaxies, caught before the formation of the red sequence.

145.09 – Comparing SFR estimators for IR-luminous galaxies at z~2 in CANDELS

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Contributing teams: The CANDELS collaboration

Galaxy formation and evolution studies rely on the robust determination of galaxy properties such as stellar masses and star formation rates (SFR) to distinguish between star-bursting galaxies main sequence galaxies and those in the process of quenching and reveal the underlying processes causing these phenomena. We estimate SFRs of galaxies at z~2 in the GOODS-S, UDS and COSMOS CANDELS fields in 3 different ways: 1) from SED-fitting to the optical/IR, 2) from far-IR luminosities from Herschel and 3) measurements of the far-UV luminosity and spectral slope. While for most objects the different estimators agree, we find a subsample of galaxies classified as pseudo-quiescent by the SED-fit. Here we investigate possible reasons for this misclassifications and present potential remedies.

145.10 – High-Redshift Supernovae Behind CLASH Galaxy Clusters

Brandon Patel[1], Curtis McCully[1], Thomas Holoien[1, 5], Or Graur[2, 3], Steven A. Rodney[4], Adam G. Riess[4]
1. Rutgers University, Piscataway, NJ, United States. 2. American Museum of Natural History, New York, NY, United States. 3. Tel-Aviv University, Tel-Aviv, Israel. 4. The Johns Hopkins University, Baltimore, MD, United States. 5. Ohio State University, Columbus, OH, United States.
Contributing teams: CLASH Collaboration

The Cluster Lensing And Supernova survey with Hubble (CLASH; Postman et al. 2012) was a 524-orbit multi-cycle treasury program to observe 25 galaxy clusters each in 16 broadband filters with WFC3 and ACS. One of the many science goals of CLASH was the detection and analysis of supernovae (SNe) at both intermediate and high redshifts. Here, we present initial results for three SNe located in the background of the targeted clusters and subject to gravitational lensing magnification.

145.11 – UV-bright Clumps in Star-forming Galaxies at 0.5<z<3 in CANDELS Fields: Clump Detection and Number Count

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Contributing teams: The CANDELS collaboration

A common feature of star-forming galaxies (SFGs) at z>1 is the existence of giant star-forming clumps, with typical size of 1 kpc and mass of 10^{7-9} solar mass. These clumps, prominent and most easily detected in the rest-frame UV images, are fundamental to our understanding of the evolution of early gas-rich disks, accretion history of galaxies, and formation of bulges. However, their origin and evolution are still unclear. It is not even clear if they resemble the star-burst regions or bulges of today's galaxies. To understand the evolution and duration of this clumpy star formation mode, a complete census on clumpy galaxies at all redshifts with rest-frame UV observations is needed. We will use the CANDELS data in the GOODS-S and UDS fields to address one essential question: the frequency of clumps in SFGs at 0.5<z<3. In this work, clumps are detected from the rest-frame UV images by an automated clump finder, with the detection ability and completeness well evaluated by fake clumpy galaxies. We will present the fractional UV luminosity function of clumps in different redshift and stellar mass bins and study the fraction of star formation that the clumps contribute to their host galaxies. We will also compare the observations with our hydrodynamic cosmological simulations.

145.12 – CLASH: Assembly Histories of Brightest Cluster Galaxies

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Contributing teams: CLASH Collaboration

Brightest Cluster Galaxies (BCGs) rank among the most massive and luminous galaxies in the Universe. Using state-of-the-art population synthesis modeling techniques, we infer the ages, stellar metallicities, and stellar mass content for a sample of 15 BCGs from the multi-wavelength Cluster Lensing And Supernova survey with Hubble (CLASH) observations. We do this analysis over many spatial resolution elements for each BCG, to construct two-dimensional maps for each of these properties,

and to test the hypothesis from galaxy formation models that the stellar populations within BCGs form at high redshift, whereas the BCGs themselves assemble their stellar mass hierarchically by accreting and merging with less massive galaxies at lower redshift.

145.13 – The Concentration-Mass Relation from CLASH clusters using galaxy dynamics

Doron Lemze[1], Andrea Biviano[2], Elinor Medezinski[1], Piero Rosati[3], Italo Balestra[2, 4], Amata Mercurio[4], Stephanie Jouvel[5], Mario Nonino[2], Keiichi Umetsu[6], Marc Postman[7], Holland Ford[1], Daniel Kelson[8], Maria Pereira[9], Eiichi Egami[9]

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Galaxy clusters play a key role in testing cosmological models and in constraining the properties of dark matter. One of these key tests is the mass density profile of clusters - the concentration-mass relation. There is a reported tension between the observed concentration-mass relation and the one theoretically expected using simulated galaxy clusters, where the observed clusters appear to have higher concentration than simulated clusters of similar total mass. In The Cluster Lensing And Supernova survey with Hubble (CLASH), we use different and independent techniques to estimate the mass distribution in clusters. The comparison between different techniques offers an observational test of the techniques and understanding of the systematics. In this work, we estimate the concentration-mass relation for about 8 (at the $0.2 <\sim z <\sim 0.6$ redshift range) of the 20 X-ray selected CLASH clusters using galaxy dynamics. We use a unique spectroscopic data set with more than about 300 cluster members per cluster. Finally, we compare our results to the theoretical expected ones and to the estimations derived using the lensing technique.

145.15 – Massive Quiescent Disk Galaxies in the CANDELS survey

Aurora Kesseli[1], Elizabeth J. McGrath[1]
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Contributing teams: CANDELS collaboration

Using data from the GOODS-S field of the CANDELS survey, we find evidence for an increasing fraction of disk-dominated galaxies at high-redshift (z~2) among the quiescent, or non-star-forming galaxy population, in agreement with a growing body of evidence from recent results in the literature. We selected all galaxies with mass M>1010 Msun within the redshift range $0.5 \le z \le 2.5$, and imposed a two-color selection criteria using rest-frame U, V, and J-band flux to separate quiescent from star-forming galaxies. From this sample, we performed a qualitative visual classification and a quantitative classification using the galaxy-fitting program Galfit. Of the original 140 quiescent galaxies, 23 have a disk component that contributes 50% or more of the total integrated galaxy light, and most of these are at high-redshift. At a redshift of $z \sim 2$ a significant fraction of all quiescent galaxies showed strong disk components with 30% being disk-dominated. We also find that massive disk galaxies seem to live in less densely populated environments while massive ellipticals live in environments with more neighbors, which leads us to believe that there are two mechanisms for the creation of massive quiescent galaxies. For the disks, the lower density environment and the disk nature of these galaxies lead us to favor cold streams over the major merger model of galaxy formation. The ellipticals, which live in higher density environments, could be assembled through major mergers of already aged stellar populations (e.g., dry mergers). This research is supported by the Clare Boothe Luce Foundation.

145.16 – KPC-SCALE STUDY OF SUBSTRUCTURES INSIDE GALAXIES out to z ~ 1.3

Shoubaneh Hemmati[1], Bahram Mobasher[1], Sarah Miller[1, 2], Hooshang Nayyeri[1]
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Studying the resolved properties of galaxies in kpc scale has the capability to address major questions in galaxy structure formation and stellar properties evolution. We use a unique sample of 129 morphologically inclusive disk-like galaxies in the redshift range 0.2<z<1.3, spread over both GOODS fields with available dynamics from the Deep Imaging Multi-Object Spectrograph (DEIMOS) on the KECK II telescope, with extended integration times leading to significant improvements in determining rotational velocity for each galaxy. We take advantage of Hubble Space Telescope (HST) ACS and WFC3 mosaics from the CANDELS program, to perform SED modeling per resolution element in each galaxy and produce resolved

rest-frame (U-V) color, stellar mass, star formation rate, age and extinction map for each galaxy. We analyze the effect of changing the Metallicity from solar to sub-solar on all our measurements. We identify red and blue regions inside galaxies based on their rest-frame (U-V) color maps with an innovative method. We show that red regions have higher stellar masses and older ages compared to the blue regions in galaxies. We also demonstrate that red regions are on average closer to the center of the galaxy than the blue regions and their spatial distance does not show a significant evolution with redshift and stellar mass of the host galaxy. Investigating the specific star formation rate evolution with redshift and dynamical mass, we notice that the evolutions in the whole galaxies are in perfect agreement with predictions from theory and previous observations. Blue regions show significantly higher sSFR and also higher slopes with redshift and dynamical mass compared to the whole galaxies and red regions are below the well-defined relation for the main sequence of star forming galaxies.

145.17 – Evolutionary Trends of Massive Spheroidal Galaxies from 0.6<z<2.5 in the CANDELS UDS Field

Zachary Rizer[1], Daniel H. McIntosh[1], Jeyhan S. Kartaltepe[2], Anton M. Koekemoer[3], Arjen van der Wel[4], Stijn Wuyts[5], Eric F. Bell[6], Christopher Conselice[7]
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Contributing teams: The CANDELS Collaboration

Spheroidal galaxies are linked to the buildup of massive quiescent galaxies. Yet, it remains unclear whether spheroid formation or quenching came first. Does the process of galactic quenching always produce a spheroid, or does the production of a spheroid lead to the galaxy being quenched? Using a new comprehensive catalog of visual classifications based on the HST/WFC3 imaging from the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS), we study the population of visually classified pure-spheroid ellipticals and bulge-dominated galaxies with Mstar > 10^10 Msun over a wide redshift range (0.6 < z < 2.5) in the Ultra Deep Survey (UDS) field. We explore rest-frame UVJ color as a function of redshift and we find a clear buildup of quiescent spheroidal systems among massive galaxies with decreasing redshift, accompanied by a non-evolving low fraction (10-20%) of star-forming systems. These results are consistent with the steady production of new spheroids that are subsequently quenched. We find quantitatively similar results using samples based solely or jointly on Sersic n>2 selection. Additionally, we find little evolution in the high (60-80%) bulge-dominated fraction among non-star-forming galaxies over a significant portion of cosmic time. Whatever mechanisms are responsible for the buildup of the massive quiescent population, they preferentially add spheroidal systems. With the remaining CANDELS fields, we will quadruple our sample size and constrain these evolutionary trends as a function of stellar mass.

146 – Exoplanets and Kepler Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

146.01 – Photometry Using Kepler "Superstamps" of Open Clusters NGC 6791 & NGC 6819

Charles A. Kuehn[1], Jason Drury[1], Dennis Stello[1], Timothy R. Bedding[1]
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The Kepler space telescope has proven to be a gold mine for the study of variable stars. To conserve bandwidth, Kepler only returns a handful of pixels surrounding each star on the target list. Unfortunately, this omits a large number of stars in the Kepler field. Fortunately, for the open clusters NGC 6791 and NGC 6819, Kepler also reads out larger superstamps which contain complete images of the central region of each cluster. These cluster images can be used to study additional stars in the open clusters which were not originally on Kepler's target list. We present preliminary results from using traditional photometric techniques to identify and analyze additional variable stars from these superstamp images.

146.02 – Long-Term Quadrature Light Variability in Early Type Interacting Binary Systems

Geraldine J. Peters[1], Robert E. Wilson[2], Todd R. Vaccaro[3]
1. University of Southern California, Los Angeles, CA, United States. 2. University of Florida, Gainesville, FL, United States. 3. St. Cloud State University, Saint Cloud, MN, United States.

Four years of Kepler observations have revealed a phenomenon in the light curves of short-period Algol-type eclipsing binaries that has never been reported from ground-based photometry. These systems display unequal brightness at their quadrature phases that numerically reverses over a time scale of about 100-400 days. We call these systems L/T (leading hemisphere/ trailing hemisphere) variables. Twenty-one such systems have so far been identified in the Kepler database and at least three classes of L/T behavior have been identified. The prototype is WX Draconis (A8V + K0IV, P=1.80 d) which shows L/ T light variations of 2-3%. The primary is a delta Scuti star with a dominant pulsation period of 41 m. The Kepler light curves are being analyzed with the 2013 version of the Wilson-Devinney (WD) program that includes major improvements in modeling star spots (i.e. spot motions due to drift and stellar rotation and spot growth and decay). Preliminary analysis of the WX Dra data suggests that the L/T variability can be fit with either an accretion hot spot on the primary (T = 2.3 T_phot) that jumps in longitude or a magnetic cool spotted region on the secondary. If the latter model is correct the dark region must occupy at least 20% of the surface of the facing hemisphere of the secondary if it is completely black, or a larger area if not completely black. In both hot and cool spot scenarios magnetic fields must play a role in the activity. Echelle spectra were recently secured with the KPNO 4-m telescope to determine the mass ratios of the L/T systems and their spectral types. This information will allow us to assess whether the hot or cool spot model explains the L/T activity. Progress toward this goal will be presented. Support from NASA grants NNX11AC78G and NNX12AE44G and USC's Women in Science and Engineering (WiSE) program is greatly appreciated.

146.03 – Algorithms for Kepler Long-Cadence Observations of Periodic Variable Stars

Kenneth J. Mighell[1]
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Several algorithms are presented which can enable otherwise problematic long-cadence 90-day observations from the Kepler Mission data archive to be used for the analysis of periodic variable stars. This study was partially funded by the Kepler Guest Observer grant NNX10AC52G.

146.04 – Mining the Kepler Data using Machine Learning

Lucianne Walkowicz[1], Alex R. Howe[1], Revant Nayar[1], Edwin L. Turner[1], Jeffrey Scargle[2], Victoria Meadows[3], Anthony Zee[4]
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Kepler's high cadence and incredible precision has provided an unprecedented view into stars and their planetary companions, revealing both expected and novel phenomena and systems. Due to the large number of Kepler lightcurves, the discovery of novel phenomena in particular has often been serendipitous in the course of searching for known forms of variability (for example, the discovery of the doubly pulsating elliptical binary KOI-54, originally identified by the transiting planet search pipeline). In this talk, we discuss progress on mining the Kepler data through both supervised and

unsupervised machine learning, intended to both systematically search the Kepler lightcurves for rare or anomalous variability, and to create a variability catalog for community use. Mining the dataset in this way also allows for a quantitative identification of anomalous variability, and so may also be used as a signal-agnostic form of optical SETI. As the Kepler data are exceptionally rich, they provide an interesting counterpoint to machine learning efforts typically performed on sparser and/or noisier survey data, and will inform similar characterization carried out on future survey datasets.

147 – HAD III: Poster Session
Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

147.01 – Urania in the Marketplace: The Timepieces

Kenneth S. Rumstay[1]
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During the twentieth century astronomical imagery was frequently incorporated, by makers of a wide variety of consumer goods, into advertisements which appeared in popular magazines in America. These images were usually intended to suggest a level of precision and reliability for the product associated (at least in the public conscience) with the science of astronomical observation. Perhaps more than any other item encountered in daily life, the personal timepiece was expected to exhibit these attributes. During the prosperous 1920's, two watch manufacturers in particular used astronomical associations to extoll the quality of their wares. One was the Elgin National Watch Company, an American firm founded in Chicago in 1864 which remained in business until 1968. The other was the Swiss firm Longines (more properly the Compagnie des Montres Longines Francillon S.A.); based in Saint-Imier since its founding in 1832, this firm has been producing luxury watches for 182 years. Both produced full-page ads for wide-circulation magazines such as The National Geographic, The Atlantic Monthly, and The Saturday Evening Post. While enticing readers to purchase a new watch as a gift or for oneself, these ads provided a look into the world of the professional astronomer. Examples of advertisements by these and other watch manufacturers, spanning the period 1897 to 1967 are presented. Particularly amusing is a personal testimonial from the English owner of an American Waltham watch, who had chided Britain's Astronomer Royal for dropping the Greenwich time ball just a tad too early.

147.02 – 50 Years of the Astro-Science Workshop at the Adler Planetarium

Mark Hammergren[1], Michael W. Martynowycz[2, 1], Gayle Ratliff[2, 1]
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Since 1964, the Adler Planetarium has hosted a program for highly motivated and interested high-school students known as the Astro-Science Workshop (ASW). Created in response to the national "call to arms" for improved science education following the stunning launch of Sputnik, ASW was originally conducted as an extracurricular astronomy class on Saturday mornings throughout the school year, for many years under the leadership of Northwestern University professor J. Allen Hynek. A gradual decline in student interest in the 1990's led to a redesign of ASW as a summer program featuring hands-on, student-driven investigation and experimentation. Since 2002, ASW has been organized and taught by graduate student "scientist-educators" and funded through a series of grants from the NSF. For the past seven years, students have designed, built, and flown experiments on helium balloons to altitudes of around 30 km (100,000 feet). Here, as we enter its 50th anniversary, we present the history of the Astro-Science Workshop, its context among the small but still vibrant community of post-Sputnik science enrichment programs, and its rich legacy of inspiring generations of astronomers and other explorers.

147.03 – Could our Understanding of Post-Main Sequence Stellar Evolution have been Hastened? The, Errantly Dismissed, 1930's Discovery of Subgiant Stars by the Mount Wilson Observatory Spectroscopists

Rachael Beaton[1], Alan Sandage[2], Steven R. Majewski[1]
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In the early 20th century, the astronomical community was focused on the formidable challenge posed by the questions of how stars are structured, powered and evolve. Key to this understanding was appropriate placement of stars on the Hertzsprung-Russell diagram and the measurement of absolute luminosities (and thus distances) for large samples of stars spanning each phase of evolution. The technique of spectroscopic parallaxes, determination of absolute magnitudes from luminosity sensitive spectral lines, had great potential to generate large samples of stars without the severely limiting restrictions and biases of other geometric parallax techniques. In a seminal 1935 catalog, the Mount Wilson Observatory spectroscopists produced an H-R diagram for 4,179 stars using this method, and identified a distinct grouping of "90 stars of intermediate luminosity" lying between the already known giant and dwarf sequences. Currently known as subgiants, these stars provided a crucial, and hitherto missing, evolutionary link between the dwarf and giant phases of evolution and could have definitively ruled out the prevailing giant-to-dwarf contraction hypothesis postulated by Henry Russell. What caused a several decade delay in the appreciation of the transitory role of these stars in stellar evolution? We review the criticisms of the spectroscopic parallax method that ultimately resulted in the dismissal of Mt. Wilson results for subgiant class stars. By comparing the Mt. Wilson parallaxes with trigonometric values from Hipparcos, we show that the concerns, while theoretically well-posed, were ultimately overstated and that the spectroscopic parallaxes over all spectral types are remarkably robust. The existence of the subgiant branch in the 1935 publication provided a fundamental clue to stellar evolution, but one that was largely ignored (and remains largely uncredited). The stellar evolutionary path through subgiants

was only verified with their striking rediscovery via accurate photometry of star clusters decades later.

148 – Instrumentation: Ground or Airborne Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

148.01 – RIMAS - rapid reaction near infrared imager-spectrometer

Alexander Kutyrev[2, 1], Vicki Toy[2], Sylvain Veilleux[2], John Capone[2], Frederick D. Robinson[3, 2], Gennadiy N. Lotkin[3, 2], Samuel H. Moseley[1], Neil Gehrels[1], Stuart N. Vogel[2]
1. NASA's GSFC, Greenbelt, MD, United States. 2. UMCP, College Park, MD, United States. 3. Global Science & Technology, Inc., Greenbelt, MD, United States.

We are presenting the design and progress on RIMAS - Rapid near infrared IMAger-Spectrometer. The primary goal of this instrument is to rapidly follow up near infrared photometry of the GRB afterglows to determine the redshift and potentially IGM properties via high resolution spectroscopy. RIMAS is a fully cryogenic instrument designed for photometry, low resolution spectroscopy and high resolution spectroscopy. The instrument is placed in a dewar cooled by a Gifford-McMahon cryocooler for continuous operation on the telescope. Its primary purpose is to observe the GRB afterglow with a fast reaction within minutes. The optical layout of the instrument arranged with two arms, YJ and HK filters, via dichroic allows to have a broad spectral range coverage. With broad spectral coverage and both imaging and spectral modes available, RIMAS will be a flexible tool for a variety of imaging and spectroscopic studies that require fast reaction. This project is a collaboration of GSFC, University of Maryland at College Park and Lowell observatory.

148.02 – Rapid GRB Photometry with RIMAS

Vicki Toy[1], Alexander Kutyrev[2, 1], Sylvain Veilleux[1], John Capone[1], Frederick D. Robinson[3, 2], Gennadiy N. Lotkin[3, 2], Samuel H. Moseley[2], Neil Gehrels[2], Stuart N. Vogel[1]
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The Rapid infrared IMAger-Spectrometer (RIMAS) is a quick near-infrared gamma-ray burst (GRB) afterglow follow-up instrument that can be run in either photometric imaging mode or spectroscopy mode. RIMAS covers four photometric bands: Y (0.97-1.08 um), J (1.11-1.33 um), H (1.48-1.78 um), and K (2.00-2.39 um). The wavelength coverage is separated into two optical arms (YJ and HK) and can acquire simultaneously between arms. When RIMAS is run in photometric imaging mode, we will be able to identify GRB afterglows and calculate redshifts for GRBs with Lyman alpha breaks. We present the status of RIMAS's detector development that consists of a guiding InSb detector and two HgCdTe 2k x 2k (H2RG) detectors as well as current noise characterization results. We report RIMAS's photometric imaging limiting magnitude estimates and comparisons between RIMAS and other near-infrared GRB afterglow imaging instruments.

148.03 – The future of rapid GRB afterglow spectroscopy with RIMAS

John Capone[1], Alexander Kutyrev[2, 1], Sylvain Veilleux[1], Vicki Toy[1], Frederick D. Robinson[3, 2], Gennadiy N. Lotkin[3, 2], Samuel H. Moseley[2], Neil Gehrels[2], Stuart N. Vogel[1]
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The Rapid Infrared IMAger / Spectrometer (RIMAS) is designed to observe gamma-ray burst (GRB) afterglows in the near-infrared (NIR, 0.9 - 2.4 microns) beginning within minutes of a burst's detection. The instrument will include low (R ~ 30) and moderate (R ~ 4500) resolving power spectroscopy across the instrument's bandpass. RIMAS will be one of five instruments continuously mounted on the 4.3 meter Discovery Channel Telescope (DCT). Following its commissioning on the DCT next year, RIMAS will be a new resource for obtaining quality spectra of GRB afterglows by observing minutes after a burst alert rather than hours, as is currently common. Expected spectroscopic performance in each configuration is presented and compared with existing facilities.

148.04 – The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII): System Design, Progress, and Plans

Stephen Rinehart[1], Maxime Rizzo[2], Todd Veach[1, 4], Arnab Dhabal[2], Dominic J. Benford[1], Robert F. Silverberg[1], Dale J. Fixsen[2], Richard K. Barry[1], Richard Barclay[1], Johannes Staguhn[3], Stephen F. Maher[1], David Leisawitz[1], Lee G. Mundy[2], Christine Jhabvala[1]
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The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII) is an 8-meter far-infrared (30-90 micron) interferometer designed to fly on a high-altitude scientific balloon, providing subarcsecond angular resolution at these wavelengths. For the first flight, currently planned for 2015, the primary scientific target will be regions of clustered star formation, where the spatially-resolved spectroscopy provided by BETTII will provide unique new data that complements the data from Herschel and Spitzer. The overall design of BETTII is complete, and fabrication and testing of subsystems is under way. We provide an overview of the BETTII design, and discuss current development work. We also outline future plans designed to lead us to a successful launch in 2015.

148.05 – The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII): Optical Design

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Here we present the optical design for The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII), an 8-meter far-infrared interferometer designed to fly on a high-altitude scientific balloon. The optical design is separated into warm and cold optics with the cold optics further separated into the far-infrared (FIR) (30-90 microns) and near-infrared (NIR) (1-3 microns). The warm optics are comprised of the twin siderostats, twin telescopes, K-mirror, and warm delay line. The cold optics are comprised of the cold delay line and the transfer optics to the FIR science detector array and the NIR steering array. The field of view of the interferometer is 2', with a wavelength range of 30-90 microns, 0.5" spectral resolution at 40 microns, R~200 spectral resolution, and 1.5" pointing stability.

148.06 – The Balloon Experimental Twin Telescopes for Infrared Interferometry (BETTII): targets and calibration

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BETTII is an 8 meter baseline interferometer that operates in the 30-90 micron wavelength range. The cryogenic, double-Fourier instrument provides sub-arcsecond angular resolution and R~20 spectral resolution, and is designed to study star formation and active galactic nuclei. The instrument is scheduled for an 8-hour stratospheric balloon flight from Fort Sumner, NM, in the fall of 2015. Given the length of the flight, it is important to select the appropriate calibrators and targets that will optimize our chances to reach mission success. We discuss the flux, phase, and bandpass calibrators that we could use to understand instrumental effects in the system, and present a sensitivity analysis that establishes the flux of the faintest detectable source, given the mission's parameters and certain tolerances on the control system, the optics, and the cryogenic instrument. We select a set of targets that BETTII could study, and explain how the new data will help answer scientific questions about star formation and AGN.

148.07 – Timing Sunsets with Smartphones: Proof of Concept for a Citizen Science Project that Quantifies the Atmosphere and Supports Astronomical Observations

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Current models that predict the times of sunrise and sunset are only accurate, typically, to a few minutes. Variations in atmospheric refraction contribute to the differences between computed and observed times. At high latitudes, slight changes in refraction can cause the Sun to remain continuously above the horizon instead of appearing to set. A substantial collection of observations would help constrain atmospheric models, which should, in turn, complement astronomical observations through improved understanding of air stability, refraction, and transparency. We report on a small project recording data from a few smartphones as a proof of concept for a possible larger scale citizen science effort.

148.08 – Shared Skies Partnership: A Dual-Site All-Sky Live Remote Observing Initiative for Research and Education

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The University of Southern Queensland's Mt. Kent Observatory in Queensland, Australia, and the University of Louisville's Moore Observatory in Kentucky, USA, are collaborating in the development of live remote observing for research, student training, and education. With a focus on flexible operation assisted by semi-autonomous controllers, rather than completely robotic data acquisition, the partnership provides interactive hands-on experience to students at all levels, optimized performance based on real-time observations, and flexible scheduling for transient events and targets of opportunity. Two sites on opposites sides of the globe cover the entire sky, and for equatorial regions allow nearly continuous coverage. The facilites include 0.5-m corrected Dall-Kirkham (CDK) telescopes at both sites, a 0.6 m Ritchie-Chretien telescope at Moore, and a new Nasmyth design 0.7-meter CDK at Mt. Kent instrumented for milli-magnitude precision photometry and wide field imaging, with spectrographs under development. We will describe the operational and data acquisition software, recent research results, and how remote access is being made available to students and observers.

148.09 – Performance Characterization of KAPAO, a Low-Cost Natural Guide Star Adaptive Optics Instrument

Joseph Long[1], Philip I. Choi[1], Scott A. Severson[2], Erik Littleton[4], Katherine Badham[2], Dalton Bolger[1], Christian Guerrero[4], Fernando Ortega[1], Jonathan Wong[1], Christoph Baranec[3], Reed L. Riddle[3]

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We present a software overview of KAPAO, an adaptive optics system designed for the Pomona College 1-meter telescope at Table Mountain Observatory. The instrument is currently in the commissioning phase and data presented here are from both in-lab and on-sky observations. In an effort to maximize on-sky performance, we have developed a suite of instrument-specific data analysis tools. This suite of tools aids in the alignment of the instrument's optics, and the optimization of on-sky performance. The analysis suite visualizes and extends the telemetry output by the Robo-AO control software. This includes visualization of deformable mirror and wavefront sensor telemetry and a Zernike decomposition of the residual wavefront error. We complement this with analysis tools for the science camera data. We model a synthetic PSF for the Table Mountain telescope to calibrate our Strehl measurements, and process image data cubes to track instrument performance over the course of an observation. By coupling WFS telemetry with science camera data we can use image sharpening techniques to account for non-common-path wavefront errors and improve image performance. Python packages for scientific computing, such as NumPy and Matplotlib, are employed to complement existing IDL code. A primary goal of this suite of software is to support the remote use of the system by a broad range of users that includes faculty and undergraduate students from the consortium of member campuses.

148.10 – Assembly and First-Light of KAPAO, a Low-Cost Natural Guide Star Adaptive Optics System

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We present a hardware overview of KAPAO, an adaptive optics system designed for the Pomona College 1-meter telescope at Table Mountain Observatory (TMO). We describe the system architecture (designed for robust remote-observing), lab performance results, and first-light observations. The system is designed around off-axis parabola (OAP) relays to maximize throughput from visible to near-infrared wavelengths. The major active components consist of a piezo-driven tip-tilt mirror (TT) and a 140-actuator MEMS (microelectromechanical) deformable mirror (DM). The camera components include a high-speed wavefront sensor and the dual science channels: a near-infrared InGaAs detector, and a high-speed visible camera for Lucky imaging. System performance is highly dependent on optical alignment; we summarize some of the alignment techniques we developed. The instrument is currently in the commissioning phase. We present results of in-lab and on-sky performance tests that include system throughput, closed-loop residual wavefront errors and image quality. The KAPAO project is a consortial effort of undergraduate institutions, in which students have been instrumental in all aspects of the optical design and hardware assembly.

148.11 – LoFASM's FPGA-based Digital Acquisition System

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The Low Frequency All Sky Monitor (LoFASM) is a distributed array of dipole antennas that are sensitive to radio frequencies from 10 to 88 MHz. LoFASM consists of antennas and front end electronics that were originally developed for the Long Wavelength Array (LWA) by the U.S. Naval Research Lab, the University of New Mexico, Virginia Tech, and the Jet Propulsion Laboratory. LoFASM, funded by the U.S. Department of Defense, will initially consist of 4 stations, each consisting of 12 dual-polarization dipole antenna stands. The primary science goals of LoFASM will be the detection and study of low-frequency radio transients, a high priority science goal as deemed by the National Research Council's decadal survey. The data acquisition system for the LoFASM antenna array will be using Field Programmable Gate Array (FPGA) technology to implement a real time full Stokes spectrometer and data recorder. This poster presents an overview of the current design and digital architecture of a single station of the LoFASM array as well as the status of the entire project.

148.12 – Progress on the Low Frequency All Sky Monitor

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The Low Frequency All Sky Monitor is a system of geographically separated radio arrays dedicated to the study of radio transients. LoFASM consists of four stations, each comprised of 12 crossed dipole antennas designed to operate between 10 - 88 MHz. The antennas and front end electronics for LoFASM were designed by the Naval Research Laboratory for the Long Wavelength Array project. Over the past year undergraduate students from the University of Texas at Brownsville have established LoFASM stations in Port Mansfield, Texas, at the LWA1 North Arm site in New Mexico, at the National Radio Astronomy Observatory in Green Bank, West Virginia, and NASA's Goldstone tracking complex in California. In combination with the establishment of these stations was the development of the analog hardware, which consists of custom RF power dividers/combiners, and a new custom amplifier and filter receiving system, which was developed and built in house. This poster will expound on progress in site installation and development of the analog signal chain, specifically the redesigned analog receiving system.

148.13 – Preliminary Results from CINDERS: Circularized IFUs Now Deployed using Economical Robots on SOAR

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Long slit spectroscopy provides stellar population and activity information along an entire axis of a target. Single fiber spectroscopy focuses in on specific regions of galaxies, such as the center. We discuss preliminary results from the addition of the CINDERS IFU module to the Goodman Spectrograph on the SOAR telescope, which provides the next stage, spatially resolved spectroscopy. CINDERS deploys three bundles of 61 fiber optic cables arranged in a nested circular pattern using inexpensive actuators that control 3-axis motion stages. The optics allow for 0.77" sampling of an 7" diameter region of up to three objects simultaneously in a 9'x4.5' field of view, making CINDERS ideal for clustered targets with more than 100" separation. Because approximately 78% of the bundle face is light sensitive, it is necessary to dither observations by 0.38" in a triangular pattern to adequately recover spatial resolution of the target. Using the 400 line/mm grating produces spectral coverage over 3700-7200AA at 5AA resolution. Initial system throughput measurements (excluding atmosphere), in the V-band, for one of the bundles are 65%. The initial project utilizing CINDERS involves mapping the central regions of 44 galaxies in Southern Compact Groups and determining the amount of star formation and AGN activity compared to isolated galaxies. We will discuss preliminary results for several of these groups.

148.14 – Concept for SAMOS: SOAR Adaptive-optics Multi-object Spectrograph

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We present the concept design of SAMOS, a Multi-Object Spectrograph for the laser-guided adaptive-optics module SAM of the 4.2m telescope SOAR at Cerro Pachon (Chile). SAMOS exploits the improved optical quality at visible wavelength over a 3'x3' field of view delivered by SAM to simultaneously acquire hundreds of spectra of rich, crowded fields. Slits are generated

"on-the-fly" using a MEMS device, namely a last-generation Digital Micro-Mirror Device (DMD) produced by Texas Instrument. The use of a DMD allows optimization of the slit width to the local seeing conditions and to the variable, field-dependent image sharpness. We illustrate a sample of the science investigations enabled by SAMOS and a baseline scheme of the system at the SAM station.

148.15 – The Gemini Observatory Fast-Turnaround Program

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Gemini's Fast-Turnaround Program is intended to greatly decrease the time from having an idea to acquiring the supporting data. The program will combine frequent proposal submission opportunities, rapid review, and fast preparation and execution of observations. We describe how the scheme will operate, and outline progress made towards its implementation.

148.16 – Gemini Multi-Object Spectrograph Upgrades: Hamamatsu CCDs and AO

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The Gemini Multi-Object Spectrographs (GMOS) at both Gemini North and South have provided crucial access to longslit, MOS and IFU moderate resolution optical spectroscopy for the Gemini international partnership for over a decade. The interim installment of e2v deep depletion CCDs at GMOS-N in November 2011, providing enhanced red sensitivity, was the first major upgrade for either GMOS since the implementation of the Nod&Shuffle mode in 2002. We present plans to replace the original EEV detectors in GMOS-S with new Hamamatsu CCDs, extending wavelength coverage out beyond 1.03 microns. GMOS-N upgrade to Hamamatsu CCDs will follow the successful deployment on GMOS-S. With the extension of GMOS sensitivity further to long wavelengths it becomes even more attractive to extend the number of observing modes to include adaptive optics imaging and spectroscopy. As has already been demonstrated with GEMS/GMOS-S imaging, adaptive optics in the 0.8-1 micron wavelength regime on Gemini can effectively transform IQ70 conditions to IQ20 and more than double the spatial resolution over the natural seeing. We present plans to move forward with plans to enable GMOS + adaptive optics as a regular user mode at both sites.

148.17 – Monitoring Atmospheric Transmission with FLAME

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Calibration of ground-based observations in the optical and near-infrared requires precise and accurate understanding of atmospheric transmission, at least as precise and accurate as that required for the spectral energy distributions of science targets. Traditionally this has used the Langley extrapolation method, observing targets and calibrators over a range of airmass and extrapolating to zero airmass by assuming a plane-parallel homogeneous atmosphere. The technique we present uses direct measurements of the atmosphere to derive the transmission along the line of sight to science targets at a few well-chosen wavelengths. The Facility Lidar Atmospheric Monitor of Extinction (FLAME) is a 0.5m diameter three Nd:YAG wavelength (355nm, 532nm & 1064nm) elastic backscatter lidar system. Laser pulses are transmitted into the atmosphere in the direction of the science target. Photons scattered back toward the receiver by molecules, aerosols and clouds are collected and time-gated so that the backscatter intensity is measured as a function of range to the scattering volume. The system is housed in a mobile calibration lab, which also contains auxiliary instrumentation to provide a NIST traceable calibration of the transmitted laser power and receiver efficiency. FLAME was designed to create a million photons per minute signal from the middle stratosphere, where the atmosphere is relatively calm and dominated by molecules of the well-mixed atmosphere (O2 & N2). Routine radiosonde measurements of the density at these altitudes constrain the scattering efficiency in this region and, combined with calibration of the transmitter and receiver, the only remaining unknown quantity is the two-way transmission to the stratosphere. These measurements can inform atmospheric transmission models to better understand the complex and ever-changing observatory radiative transfer environment. FLAME is currently under active development and we present some of our ongoing measurements.

148.18 – Learning from AESoP: NIST-traceable Spectroradiometric Calibration of Stars

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The creation of a homogeneous set of NIST-traceable standard stars with reproducible measurement errors is an enabling factor for fundamental physical interpretation of imaging radiometric and spectroradiometric data. Broader impacts of these stars include use in calibrating optical instrumentation, including on-orbit sensors, and monitoring the wavelength-dependent transmission of Earth's atmosphere. The Astronomical Extinction Spectrophotometer (AESoP) is designed to accurately measure the spectra of stars and calibrate them to a NIST transfer standard. AESoP is a 100mm objective spectrometer built on a Takahashi 106ED refractor, using a 90 line/mm grating to produce a spectrum from 530 to 950nm in first order and 350 to 600nm in second order. Accurately autoguided stellar spectra are maintained on spectrophotometer pixels calibrated to a co-mounted NIST calibrated transfer standard, CAL. CAL is identical to AESoP except for the objective grating. The telescopes are mounted in a mobile optical laboratory, also containing a monochromator to provide a wavelength-tunable calibration source. The monochromator illuminates a collimator simultaneously viewed by AESoP and CAL, thus allowing wavelength-dependent calibration of the AESoP detector to the NIST-calibrated CAL detector. The resulting stellar spectra, when reduced and corrected for wavelength-dependent atmospheric extinction, are NIST-traceable spectroradiometric standards. The AESoP/CAL telescopes are being tested in the field. Operational procedures, stellar measurment performance, and calibration data will be discussed. AESoP development and application is funded by NSF Grant AST-1009878 and NIST Award 60NANB9D9121.

148.19 – The WIYN One Degree Imager: Upgrading for the Future

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Contributing teams: ODI Team

The WIYN One Degree Imager has been in shared risk operations since February 2013. At this time, the focal plane is populated with 13 out of 64 possible Orthogonal Transfer Array (OTA) CCD detectors, yielding a science field of view of 24' x 24'. In this poster we first report on the performance of the instrument during its first year of operations. Then we will update on the progress towards improving ODI for the future: As of this writing, WIYN is acquiring a new batch of OTA detectors with a better low light level charge transfer efficiency. With the new detectors in a 6x6 detector configuration, the field of view will be increased to 48x48 arcminutes. Other ODI improvements will focus on observing efficiency, including a redesign of the filter drive mechanism and an improvement on WIYN's pointing accuracy. Commissioning of upgraded 6x6 ODI is scheduled for late 2014.

148.20 – Science with ODI: An overview of ongoing and upcoming research with the WIYN Observatory's new large format imager

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Contributing teams: WIYN Consortium

The WIYN Observatory's One Degree Imager (ODI) project has completed the initial construction phase by populating a partial focal plane, referred to as pODI. This first milestone of the larger project provides a core imaging area of 24 arcmin x 24 arcmin, along with four 8 arcmin x 8 arcmin regions offset from the core area. The 0.11 arcsec pixels provide good sampling for WIYN's often excellent seeing. Astronomers at each of WIYN's university partners, Wisconsin, Indiana, and Yale, as well as observers at other institutions using national access time provided by NOAO, have observed with pODI in support of a variety of investigations. The subjects of the research projects include very nearby targets, such as a main belt asteroid that exhibits a tail nearly a quarter of a degree long (Rajagopal et al.). Farther away, Friel et al. are studying the effects of rotation and tidal fields on Galactic globular clusters. Examples of extragalactic projects include a wide-field, multi-color imaging survey of the globular cluster populations of giant spiral, S0, and elliptical galaxies, with the aim of investigating the galaxies' formation and evolution (Rhode et al.) and the search for low surface brightness optical counterparts to HI sources revealed by the ALFALFA survey (Salzer et al.). Two complementary pipelines, one written in IRAF and the other in python, are processing the pODI data within the Pipeline, Portal, and Archive (PPA) structure developed by Indiana University's Pervasive Technology Institute. Users are able to access the data entirely within the portal interface, or they can download the processed images to a local machine. The pODI instrument is expected to continue operations through spring 2014, at which time it will be removed for an upgrade to the next stage of the instrument. It will return to the telescope approximately 6 months later with a 48 arcmin x 48 arcmin filled field of view.

148.21 – Silicon Powder Filters for Large-Aperture Cryogenic Receivers

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Upcoming experiments probing for the existence of B-mode polarization in the cosmic microwave background (CMB) will require large arrays of background-limited detectors. This will necessitate the use of cryogenic receivers with large-aperture

vacuum windows and correspondingly large low-pass infrared-blocking filters to minimize thermal load. Large-diameter filters composed of absorptive dielectrics are difficult to conductively cool adequately, and thus tend to heat up and re-radiate towards the focal plane. Reflective metal-mesh filters are challenging to manufacture at such large apertures and with feature sizes small enough to effectively block 300K thermal radiation. In order to overcome these difficulties, we have developed a novel type of thermal filter that scatters, rather than reflects or absorbs, unwanted infrared radiation. Comprised of ultra-pure silicon powder distributed within a polymethylpentene (PMP) substrate, these filters are not absorptive in the infrared while being transparent to microwaves, and are comparatively straightforward to produce. By adjusting the size of the silicon particles, the frequency cut-off of these low-pass filters is fully tunable. Small scale (70mm diameter, 3mm thickness) prototypes have exhibited <10% transmission throughout the infrared spectrum and <1% transmission at the peak of the 300K blackbody spectrum, while maintaining an estimated 97% transmission in the microwave regime.

148.22 – Monitoring of Cyg A and Cas A flux densities below 100 MHz

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Contributing teams: on behalf of the LWA1 collaboration

As part of regular operation of the first station of the Long Wavelength Array, frequent beam-formed observations of Cygnus A and Cassiopeia A have been conducted in order to monitor station health and to provide a reference for calibration of other scientific experiments. The supernova remnant Cas A has been known to show flux variations that differ from the standard empirical decay rate and possibly exhibits periodic variations. Regular measurements of its low-frequency flux density are necessary for its use as calibrator and to understand its ongoing evolution. I am going to present first results from this flux density monitoring, discussing variability and observered flux ratios. Insights gained into the data quality through these and related observations of Virgo A and Taurus A as well as the influence of variations in ionospheric scintillation are presented. Implications of this work for flux density calibration, characterization of the antenna patterns, position dependent system equivalent flux densities, beam shape, and calibration stability of LWA1 are discussed as well.

148.23 – A Positional X-ray Instrumentation Test Stand For Beam-Line Experiments

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A multi-axis, motion controlled test stand has been built in the PSU 47 m X-ray beam-line for the purpose of testing X-ray instrumentation and mirrors using parallel rays. The test stand is capable of translation along two axes and rotation about two axes with motorized fine position control. The translation stages have a range of motion of 200 mm with a movement accuracy of ± 2.5 microns. Rotation is accomplished with a two-axis gimbal which can rotate 360° about one axis and 240° about another; movement with ± 35 arcsecond accuracy are achieved in both axes. The position and status are monitored using a LabView program. An XCalibr source with multiple target materials is used as an X-ray source and can produce multiple lines between 0.8 and 8 keV. Some sample spectra are shown from a Si-PIN diode detector. This system is well suited for testing X-ray mirror segments which are currently being developed.

148.24 – Development of a Low Cost Spectrometer for the Small Radio Telescope (SRT), Very Small Radio Telescope (VSRT), and Ozone spectrometer

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Several instruments used for education, outreach and scientific investigations could benefit from a low cost spectrometer. These include the Small Radio Telescope known as the "SRT", a very small radio telescope known as the "VSRT", and an 11 GHz Ozone spectrometer. The SRT is used to observe the Sun and the 21-cm hydrogen line. The SRTs, which until recently were available commercially, are still in operation at many universities and are used for student projects including measuring the Galactic rotation curve of our Galaxy. These instruments, which were initially primarily used to help teach students how to analyze scientific data, are now used for scientific investigations that have resulted in publications in science journals. Recently a low cost USB "dongle" for digital TV has become available. It has been adapted for use as a software defined radio by amateur radio groups. Linux-based software was developed to adapt the device to form a low cost digital spectrometer for the SRT by integrating open source code into the existing C code written for the SRT. Some challenges faced when trying to integrate the USB TV dongle into the SRT system and software will be discussed. To test the effectiveness of the USB TV Dongle based SRT several astronomical observations were made and compared to the older SRT system. These observations show promise for the device replacing older SRT systems at a fraction of the cost and effort and as a possible replacement for

the VSRT and Ozone spectrometer.

148.25 – Time-Domain and Transient Astronomy with the Liverpool Telescope

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A brief overview of the Liverpool Telescope, Europe's premier robotic observatory, will be given. The LT specializes in delivering high-impact results in time-domain astrophysics, and is the largest facility of its kind in the world. The LT offers a range of optical instrumentation that includes imaging, spectroscopy, and polarimetry, and will shortly commission a new near-IR camera. In the run-up to LSST operations, the LT (and it successor, LT2) will provide a valuable training-ground for a new generation of researchers active in time domain and transient astrophysics.

148.26 – Astrometric and Photometric Accuracy of the 1.3 m Robotically Controlled Telescope on Kitt Peak

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The 1.3 m (50 inch) telescope on Kitt Peak has been refurbished and provided with an autonomous scheduler. It is operated by The Robotically Controlled Telescope (RCT) consortium whose members are: South Carolina State, Villanova and Western Kentucky Universities. The facility possesses 5 board (UBVRI) and 11 narrow-band filters. Attached to the RCT camera is a 2048 x 2048 SITe SI-424A back-illuminated CCD with 24 micrometer pixels. We used over 7,000 star measurements from 37, 198s R-images to compute the astrometric and photometric accuracy. The difference of the J2000 coordinates computed from the RCT images and the J2000 Nomad catalog coordinate values in right ascension peaks at 0.058", while the declination peaks at -0.125". We obtained these astrometric results using the simplest assumptions: linear relationship between standard coordinates and measured coordinates, no color or magnitude dependency and no differential refraction (all images taken in the zenith). We express the photometric accuracy in the following manner: The Signal-to-Noise-Ratio as a function of apparent magnitude shows that the RCT is not noise dominated at m < 20 magnitude.

148.27 – Lunar Laser Ranging with Imaging Atmospheric Cherenkov Telescopes

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Lunar laser ranging is the process through which light pulses are bounced off of retroreflectors on the Moon. The travel time of the photons is measured and multiplied by the speed of light to calculate the Earth-Moon distance. The measured Earth-Moon distance can be compared to the Earth-Moon distance predicted by the theory of General Relativity. In that way, possible shortcomings of General Relativity are exposed. The current best measurements are performed by the Apache Point Observatory Lunar Laser-ranging Operation using the ARC 3.5-m Ritchey-Chretien reflector at the Apache Point Observatory yielding errors of less than 1 mm. Upon launching pulses of 3 x 10^17 photons, this telescope yields a one to two photon per pulse return. This study investigates whether the larger surface area of Imaging Atmospheric Cherenkov Telescopes, such as the four 12-m diameter Davies-Cotton dishes that are part of the Very Energetic Radiation Imaging Telescope Array System, allows for a greater photon per pulse return rate and thus a more accurate measurement of the Earth-Moon distance. The feasibility of using these telescopes for lunar laser ranging is assessed, taking into account the poorer optical quality of Davies-Cotton reflectors. It is found that the Davies-Cotton dishes cannot be used as the outgoing beams in lunar laser ranging, so the feasibility of using other telescopes located close to the Very Energetic Radiation Imaging Telescope Array System as outgoing beams is also examined. Other Imaging Atmospheric Cherenkov telescope systems are considered, and the relationship between dish size and the length of time delay present with Davies-Cotton dishes is examined.

148.28 – Analysis of DECal Scans for the Dark Energy Survey Camera

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Contributing teams: Texas A&M University, Cerro Tololo Inter-American Observatory

DECal is a calibration system to measure the total system throughput (less atmosphere) for the Dark Energy Camera, DECam, and to be used by the Dark Energy Survey, DES, as well as community users of the DECam instrument. DECal projects a narrow wavelength range of light onto a flat field screen inside the Cerro Tololo Inter-American Observatory, CTIO, dome of the 4m Blanco Telescope. The combination of data products derived from the monochromer, spectrometer, and calibrated photodiodes along with the imaged flat field screen by DECam and each of its filters allow for an analysis of the

system response as a function of wavelength, filter, focal plane position, and time. In this poster, we describe the data products and the analysis to generate system response curves and the use of the system to study other instrumental signatures.

148.29 – Design and Construction of a New 1420 MHz Receiver System for a 12-meter Radio Telescope

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During the summer of 2013, a new 1420 MHz receiver system was designed and constructed for the 12-meter radio telescope at the Pisgah Astronomical Research Institute (PARI). The new radio receiver system consists of a feedhorn (which is a duplicate of the feedhorn that is currently installed on PARI's 4.6-meter radio telescope), a low-noise amplifier, a bandpass filter, a downconverter, a SpectraCyber 1420 MHz Hydrogen Line Spectrometer, CommScope CNT-600 braided coaxial cable, and a power supply. Each component was individually tested on the preexisting 4.6-meter radio telescope receiver system before being installed on the 12-meter telescope. This testing process revealed that the spectrometer that was intended for use in the new 12-meter receiver system would require 12-bit software, which was acquired soon thereafter. The new receiver system was then assembled on a rolling cart for further testing. After the 1420 MHz receiver system was moved outside, it successfully detected its first extraterrestrial radio signal. The next step of this project was the installation of the feedhorn at the focus of the 12-meter parabolic reflector and the mounting of the additional receiver system components inside the radio frequency (RF) room of the 12-meter telescope. Following its installation on the 12-meter telescope, the new receiver system was connected to the PARI network via ethernet using a device called a SitePlayer Telnet. The 12-meter telescope was focused by taking continuum scans of Virgo A during its meridian crossing. The positioning of the feedhorn had to be adjusted several times before the new radio receiver system was precisely focused. After focusing the 12-meter telescope, spectra were taken of both the Orion Nebula and the Crab Nebula to test the abilities of the new 1420 MHz receiver system. As a final test of both the angular resolution and time resolution of the new radio receiver system, the 12-meter telescope was used to observe the pulsar PSR J0332+5434. Fourier analysis resulted in a calculated pulsar period of 0.745 seconds, which is within 0.03 seconds of the accepted value for this pulsar.

148.30 – Experiences with the Design and Construction of Astronomical Instrumentation using CASPER: The Digital Backend System

Richard M. Prestage[1], Martin Bloss[1], Joe Brandt[1], Ramon Creager[1], Paul Demorest[2], John Ford[1], Glenn Jones[2,3], Jintao Luo[2], Randy McCullough[1], Scott M. Ransom[2], Jason Ray[1], Galen Watts[1], Mark Whitehead[1]

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NRAO recently designed and built a state-of-the-art backend system for the Shanghai Astronomical Observatory's (SHAO) 65 meter radio telescope. The machine, called the Digital Backend System (DIBAS), was created from the design of the VErsatile GBT Astronomical Spectrometer (VEGAS) by adding nine incoherent pulsar search modes and eight coherent dedispersion timing modes to complement the 29 VEGAS spectral line modes. Together these modes cover all of the anticipated science requirements for the 65 meter except for VLBI. The VEGAS multi-beam spectrometer was recently designed and built for the Green Bank Telescope (GBT) through a partnership between the National Radio Astronomy Observatory (NRAO) and the University of California at Berkeley. The VEGAS spectrometer is based on a Field Programmable Gate Array (FPGA) frontend and a heterogeneous computing backend comprised of Graphical Processing Units (GPUs) and x86-64 CPUs. Working together, the hardware in this system provides processing power to analyze up to 8 dual-polarization or 16 single-polarization inputs, at bandwidths of up to 1.25 GHz per input. An aggregate of up to 10 GHz of bandwidth, dual polarization, may be simultaneously processed with the VEGAS spectrometer. As capable as this spectrometer is, it has no advanced pulsar capabilities such as were needed for DIBAS. To create DIBAS, VEGAS was augmented with new FPGA designs based on those built for the Green Bank Ultimate Pulsar Processing Instrument (GUPPI) some five years ago. GUPPI was built on earlier generations of FPGA hardware designed by the CASPER project at Berkeley. Porting the old GUPPI designs to modern hardware and wider bandwidths was a good test case to determine the portability of the FPGA designs and the utility of the toolset to help move designs between generations of FPGA chips, as well as the degree of reuse that could be obtained from the VEGAS project. This paper will explore the unique aspects of the DIBAS project, including the extremely high level of reuse of existing FPGA designs, the challenges of an aggressive schedule for the project, and the unique technical designs needed for the system, including the Python-based portable control system and GPU software.

148.31 – MINERVA: Small Telescopes, Small Planets

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MINERVA is four, dedicated, robotic 0.7-m telescopes at Mt. Hopkins that will use fiber optic cables to simultaneously feed a stable spectrograph to perform an intense campaign of precise velocimetry on the 80 brightest, nearest, Sun-like stars. Our strategy is to overcome astrophysical noise from stars though at-least-nightly observation, and to overcome instrumental noise limitations by combining temperature and pressure stability with an iodine calibration cell. The first telescope is being commissioned at Caltech, and site preparation at Mt. Hopkins is underway. The telescopes will also be outfitted with cameras for stellar photometric work and education and public outreach efforts.

148.32 – Winter sky brightness & cloud cover over Dome A

Yi Yang[3,2], Anna M. Moore[1], Jianning Fu[2], Michael C. B. Ashley[4], Xiangqun Cui[5], Longlong Feng[6,7], Xuefei Gong[5,7], Zhongwen Hu[5,7], Jon Laurence[8,9], Daniel LuongVan[4], Reed L. Riddle[1], Zhaohui Shang[7,10], Geoffrey Sims[4], John Storey[4], Nick Tothill[11], Tony Travouillon[12], Lifan Wang[3,6], Huigen Yang[7,13], Ji Yang[6], Xu Zhou[7,14], Zhenxi Zhu[6,7], Michael G. Burton[4]
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At the summit of the Antarctic plateau, Dome A offers an intriguing location for future large scale optical astronomical Observatories. The Gattini DomeA project was created to measure the optical sky brightness and large area cloud cover of the winter-time sky above this high altitude Antarctic site. The wide field camera and multi-filter system was installed on the PLATO instrument module as part of the Chinese-led traverse to Dome A in January 2008. This automated wide field camera consists of an Apogee U4000 interline CCD coupled to a Nikon fish-eye lens enclosed in a heated container with glass window. The system contains a filter mechanism providing a suite of standard astronomical photometric filters (Bessell B, V, R), however, the absence of tracking systems, together with the ultra large field of view(~85 degrees) and strong distortion have driven us to seek a unique way to build our data reduction pipeline. We present here the first measurements of sky brightness in the photometric B, V, and R band, cloud cover statistics measured during the 2009 winter season and an estimate of the transparency. In addition, we present example light curves for bright targets to emphasize the unprecedented observational window function available from this ground-based location. A ~0.2 magnitude agreement of our simultaneous test at Palomar Observatory with NSBM(National Sky Brightness Monitor), as well as an 0.04 magnitude photometric accuracy for typical 6th magnitude stars limited by the instrument design, indicating we obtained reasonable results based on our ~7mm effective aperture fish-eye lens.

148.33 – The New Instrument Suite of the TSU/Fairborn 2m Automatic Spectroscopic Telescope

Matthew W. Muterspaugh[1], Ted Maxwell[1], Michael W. Williamson[1], Francis C. Fekel[1], Jian Ge[2], John Kelly[1], Askari Ghasempour[1], Scott Powell[2], Bo Zhao[2], Frank Varosi[2], Sidney Schofield[2], Jian Liu[2], Craig Warner[2], Hali Jakeman[2], Louis Avner[2], Samuel Swihart[3], Chelsea Harrison[1], Dan Fishler[1]
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Tied with the Liverpool Telescope as the world's largest fully robotic optical research telescope, Tennessee State University's (TSU) 2m Automatic Spectroscopic Telescope (AST) has recently been upgraded to improve performance and increase versatility by supporting multiple instruments. Its second-generation instrument head enables us to rapidly switch between any of up to twelve fibers optics, each of which can supply light to a different instrument. In 2013 construction was

completed on a new temperature-controlled guest instrument building, and two new high resolution spectrographs were commissioned. The current set of instrumentation includes (1) the telescope's original R=30,000 echelle spectrograph (0.38--0.83 microns simultaneous), (2) a single order R=7,000 spectrograph centered at Ca H&K features, (3) a single-mode-fiber fed miniature echelle spectrograph (R=100,000; 0.48--0.62 microns simultaneous), (4) the University of Florida's EXPERT-3 spectrograph (R=100,000; 0.38--0.9 microns simultaneous; vacuum and temperature controlled) and (5) the University of Florida's FIRST spectrograph (R=70,000$; 0.8--1.35 or 1.4--1.8 microns simultaneous; vacuum and temperature controlled). Future instruments include the Externally Dispersed Interferometry (EDI) Testbed, a combination low resolution dispersed spectrograph and Fourier Transform Spectrograph. We welcome inquiries from the community in regards to observing access and/or proposals for future guest instruments.

148.34 – Final Design of the CHARIS Integral Field Spectrograph for the Subaru Telescope

Tyler D. Groff[1], Mary Anne Peters[1], N. J. Kasdin[1], Michael Galvin[1], Timothy Brandt[1], Michael Carr[1], Gillian R. Knapp[1], Michael W. McElwain[2], Markus Janson[3], Craig Loomis[1], Olivier Guyon[4], Frantz Martinache[4], Nemanja Jovanovic[4], Kyle Mede[6], Naruhisa Takato[4], Masahiko Hayashi[5]

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Princeton University is building the Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS), an integral field spectrograph (IFS) funded by the National Astronomical Observatory of Japan. It will be integrated with the Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) and the AO188 adaptive optics system on the Subaru telescope. CHARIS is designed to image disks and take high contrast spectra of brown dwarfs and hot Jovian planets in a coronagraphic image across J, H, and K bands. SCExAO's coronagraphs and wavefront control system will suppress quasi-static speckles to detect objects five orders of magnitude dimmer than their parent star down to an 80 milliarcsecond inner working angle. Such quasi-static speckles not only make it difficult to achieve detection, but the close packing of spectra in an IFS means neighboring speckles can contaminate the signal from the planet. The result is uncertainty in the planetary spectrum due to diffractive cross-contamination, commonly referred to as crosstalk. Post-processing techniques can subtract these speckles, but can potentially skew spectral measurements, become less effective at small angular separation (a key problem at 80 milliarcseconds), and at best can only reduce the crosstalk down to the photon noise limit of the contaminating signal. CHARIS will address crosstalk effects of a high contrast image through hardware design, which drives the optical performance and mechanical design of the instrument. In addition to providing better spectral certainty in the science data, mitigating crosstalk in hardware decreases the computational overhead required to use CHARIS images as feedback in the focal plane wavefront control loop being operated by SCExAO. Here we present the science case, and design of CHARIS from its critical design review. This highlights the choices that must be considered to design an IFS for high signal-to-noise spectra in a coronagraphic image. The design considerations and lessons learned are directly applicable to future exoplanet instrumentation for extremely large telescopes and space observatories capable of detecting rocky planets in the habitable zone.

148.35 – The HPOL Spectropolarimeter and the First 1.5 Years of Operation at Ritter Observatory

James W. Davidson[1], Karen S. Bjorkman[1], Jon E. Bjorkman[1], Jennifer L. Hoffman[2], Brian L. Babler[3], Marilyn Meade[3], Jamie R. Lomax[4], Kenneth H. Nordsieck[3], John P. Wisniewski[4], Kody A. Kamunen[5,1]

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We will report on the first year and a half of observations with the University of Wisconsin's Halfwave Polarimeter (HPOL) instrument at the University of Toledo's Ritter Observatory. HPOL is a medium resolution spectropolarimeter, providing wavelength coverage from 3200 angstroms to 1.05 microns with a 10 angstrom resolution. It was previously a facility instrument at the Pine Bluff Observatory (PBO) of the University of Wisconsin, going off-line in October 2004. We will present the calibration work performed to demonstrate the instrument and telescope stability, which is comparable to the stability of HPOL at PBO. Selected results from the first year and a half of operation will also be presented. The refurbishment of HPOL has been partially funded by a Small Research Grant from the AAS, and also by the Scott E. Smith Fund for Research at Ritter Observatory.

148.36 – The Advancement of Radio Astronomy at Brigham Young University

Charles Honick[1], Victor Migenes[1], Daniel Blakley[1]
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We are presenting on the status and future plans of the radio astronomy project at Brigham Young University. The Physics and Astronomy department and the West Mountain Observatory already have optical facilities that offer students the opportunity to observe in the optical and NIR, but not at any other wavelengths. An array is being built to allow students to obtain data in the radio spectrum. The array is being built around the already operational 4 meter dish on top of the Eyring Science Center and will eventually contain baselines up to 8 km and a 10 m dish. We currently have selected the four sites for additional baselines. The array initially will be ready to observe HI at 1420 MHz and the OH MASER lines at 1665 MHz and 1667 MHz. We present preliminary spectra in L-band (21-18cm) with the 4 meter dish. The system will be using LNA's for signal amplification and will have digital correlation and spectral analysis through CASPER. The system is locked to a rubidium clock with a GPS master. In the future, we hope to extend the frequency coverage to C-band (5 GHz).

148.37 – CHaS, the Circumgalactic H-alpha Spectrograph

Sam Gordon[1], David Schiminovich[1], Erika T. Hamden[1]
1. Columbia University, New York, NY, United States.

CHaS (the Circumgalactic H-alpha Spectrograph) is a new narrowband Integral Field Unit (IFU) spectrograph, developed by the Schiminovich Group at Columbia University in 2013. CHaS will be used to map the H-alpha emission from diffuse, low surface brightness gas around nearby galaxies as well as Galactic nebulae. A small prototype for CHaS was debuted on the 1.3m and 2.4m telescopes at MDM Observatory, on Kitt Peak, Arizona, during September, 2013. Proto-CHaS uses a microlens array placed in the image plane, which produces a 6 x 6 (3x3) arcminute spectral image of the target composed of 5 (2.5) arcsecond pixels. Each pixel is a 3nm wide spectrum centered around either H-alpha or NII emission lines, depending on the filter chosen, with R~2000. We present initial findings from the proto-type run, as well as predictions for the final, larger version of CHaS.

148.38 – Finding Radio Transients with the Murchison Widefield Array

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Contributing teams: The Murchison Widefield Array Collaboration

Explorations of the radio sky in the time-domain are an exciting frontier in astrophysics, and one where new observational capabilities will open up new windows on the universe. As one of a new generation of widefield, low-frequency radio telescopes, the Murchison Widefield Array has enormous potential to conduct blind searches for radio transients. We will discuss the expected types of sources that we hope to discover with the full array, explore some of our initial results, and highlight the capabilities of the full array that has been recently commissioned.

148.39 – SOFIA: Review of Initial Science Operations, 2010 – 2013

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The long-awaited debut of the Stratospheric Observatory for Infrared Astronomy (SOFIA) occurred with first light on May 26, 2010. Initial science flight operations in the 2010 - 2013 time frame are reviewed to obtain preliminary estimates of some general characteristics of operations to date, as a preview of what might be expected for flight operations in the near future. This includes the distribution of targets and observing time on the sky, elevation/air mass distribution, the geographic envelope of science flights, and flight altitude profiles. Solar system objects observed include Jupiter, Neptune, Pluto, several asteroids, and Comet Hartley 2. These general aspects of airborne astronomy as seen in SOFIA operations to date are factors in evaluating airborne observing efficiency, science productivity, and operations cost effectiveness. Specifically, the flight trajectories determine the fraction of observations actually made in the stratosphere, which in turn strongly affects the FIR telluric transmission and background noise, and therefore the resulting SNR of the time-constrained observations.

148.40 – Performance of Electroluminescent Flats for Precision Light Curve Photometry

Ryan L. Avril[1], Thomas E. Oberst[1]
1. Physics, Westminster College, New Wilmington, PA, United States.

We measure of the quality of flat field frames (flats) taken using an electroluminescent (EL) panel versus both dome and sky flats for purposes of calibrating visual CCD images. Classic dome and sky flats can both suffer from overall gradients and local irregularities. EL panel flats have recently grown in popularity as a third alternative, based partly on their potential to be free of such defects. We assess the flats based on their contributions to the RMS noise of long-duration light curves constructed via differential aperture photometry. The noise levels explored range from ~ 1 – few mmag, as needed for the

ground-based detection of transiting planets. The target and reference stars are deliberately permitted to drift across the CCD in order to probe pixel-to-pixel variations. Both the filter and focus are varied during the tests – the former to probe color variation in the flats, and the latter because defocusing tends to average out pixel-to-pixel variations that the flats are intended to remove. All tests were performed at the Westminster College Observatory (WCO), which belongs to the Kilodegree Extremely Little Telescope (KELT)-North follow-up network.

148.41 – Precision Astronomy with Imperfect Deep Depletion CCDs

Christopher Stubbs[1]
1. Harvard University, Cambridge, MA, United States.
Contributing teams: LSST sensor team, PanSTARRS team.

While thick CCDs do provide definite advantages in terms of increased quantum efficiency at wavelengths 700 nm$<\lambda < 1.1$ microns and reduced fringing from atmospheric emission lines, these devices also exhibit undesirable features that pose a challenge to precision determination of the positions, fluxes, and shapes of astronomical objects, and for the precision extraction of features in astronomical spectra. For example, the assumptions of a perfectly rectilinear pixel grid and of an intensity-independent point spread function become increasingly invalid as we push to higher precision measurements. Many of the effects seen in these devices arise from lateral electrical fields within the detector, that produce charge transport anomalies that have been previously misinterpreted as quantum efficiency variations. Performing simplistic flat-fielding therefore {\em introduces} systematic errors in the image processing pipeline. One measurement challenge we face is devising a combination of calibration methods and algorithms that can distinguish genuine quantum efficiency variations from charge transport effects. These device imperfections also confront spectroscopic applications, such as line centroid determination for precision radial velocity studies. Given the scientific benefits of improving both the precision and accuracy of astronomical measurements, we need to identify, characterize, and overcome these various detector artifacts. In retrospect, many of the detector features first identified in thick CCDs also afflict measurements made with more traditional CCD detectors, albeit often at a reduced level since the photocharge is subject to the perturbing influence of lateral electric fields for a shorter time interval. I provide a qualitative overview of the physical effects we think are responsible for the observed device properties, and provide some perspective for the work that lies ahead.

148.42 – Characteristics and Early Science Results of the Virgin Islands Robotic Telescope at the Etelman Observatory

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The Virgin Islands Robotic Telescope is an 0.5m robotic telescope located at the easternmost and southernmost optical observatory in the United States at a latitude of 18.5N and longitude of 65W. The observatory is located on the island of St Thomas in the USVI. Astronomers from the College of Charleston and the University of the Virgin Islands collaborate to maintain and operate the facility. Science goals of the facility include optical follow-up of high-energy transients, extra-solar planet observations, and near-Earth asteroid searches. The facility also supports a wide-reaching education and outreach program dedicated to raising the level of STEM engagement and enrichment in the USVI. We detail the characteristics, capabilities, and early results from the observatory. The observatory is growing its staff and science activities and potential topics for collaboration will be discussed.

149 – Instrumentation: Space Missions Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

149.01 – WFC3: Enhanced Data Processing Software

Megan L. Sosey[1]
1. STScI, Baltimore, MD, United States.
Contributing teams: WFC3 Instrument Team

The CALWF3 processing software and its associated routines, such as WF3CCD and WF3IR, are now available independent of the IRAF environment as part of the HSTCAL package. The previous IRAF/PyRAF version, while still available within the current STSDAS/IRAF release, will no longer be maintained or updated. The STScI archive pipeline started running the updated HSTCAL-version of the software on Sept 26, 2012. Due to accompanying changes in pipeline-dependent keywords, anyone wishing to run the most recent version of the calibration pipeline on data retrieved prior to Sept 26,2012 should re-request the data from the STSCI archive. The routines may still be accessed from the PyRAF environment by importing the new WFC3TOOLS package (released as part of the latest stsci_python). This package may also be imported into any Python session. The pipeline calibration routines may also be called directly from the system command line prompt. The WFC3TOOLS package and the CALWF3 executable are included with the HSTCAL package released alongside the latest STSDAS public release and can be downloaded from http://www.stsci.edu/institute/software_hardware/stsdas/download-stsdas.

149.02 – WFC3: Status and Advice for Cycle 22 Proposers

John W. MacKenty[1], Sylvia M. Baggett[1], Susana E. Deustua[1], Derek Hammer[1], Janice C. Lee[1], Peter R. McCullough[1], Norbert Pirzkal[1], Vera Kozhurina-Platais[1], Adam G. Riess[1]
1. STScI, Baltimore, MD, United States.
Contributing teams: Wide Field Camera 3

The Hubble Space Telescope's Wide Field Camera 3 provides observers with powerful imaging and slitless spectroscopic capabilities from 200 to 1700 nm. In this paper we present a summary of WFC3's current status and performance characteristics together with highlights of key new information for astronomers developing proposals for future science investigations. Over the past couple of years, observers have made increasing use of WFC3's ability to obtain high precision astrometric and photometric observations. We discuss improvements to the general astrometric calibration and recent advances in techniques for obtaining specialized observations with an astrometric precision better than 30 micro arc seconds. We also report on the photometric recalibration of the UVIS channel which incorporates independent solutions for the two CCD detectors resulting in improved zero points and color terms in the near ultraviolet and on measurements which demonstrate the excellent astrometric and photometric stability of this instrument. Finally, we provide advice for observers to better understand and predict astronomical backgrounds with the aim of improving the sensitivity of deep observations.

149.03 – WFC3: Understanding and Mitigating UVIS Charge Transfer Efficiency Losses and IR Persistence Effects

Sylvia M. Baggett[1], Jay Anderson[1], Knox S. Long[1], John W. MacKenty[1], Kai Noeske[1], John A. Biretta[1]
1. STScI, Columbia, MD, United States.
Contributing teams: WFC3 Team

A panchromatic instrument, Wide Field Camera 3 (WFC3) contains a UVIS channel with a 4096x4096 pixel e2v CCD array as well as an IR channel with a 1014x1014 Rockwell Scientific HgCdTe focal plane array (FPA). Both detectors have been performing well on-orbit since the installation of the instrument in the Hubble Space Telescope (HST) in May 2009. However, as expected, the harsh low-earth orbit environment has been damaging the UVIS CCDs, resulting in a progressive loss of charge transfer efficiency (CTE) over time. We summarize the magnitude of the CTE losses, the effect on science data, and the pre- and post-observation mitigation options available. The IR FPA does not suffer from accumulating radiation damage but it does exhibit persistence i.e. an after-glow from sources in previous exposures, an anomaly commonly seen in these types of IR arrays. We summarize the characteristics of persistence in WFC3, suggest methods for reducing the effects during observation planning, and describe the calibration products which are available via the Mikulski Archive for Space Telescopes (MAST) for addressing persistence in IR science data.

149.04 – WFC3: Improved WFC3 Calibration Products

Heather C. Gunning[1], Megan L. Sosey[1], Jay Anderson[1], Janice C. Lee[1], Norbert Pirzkal[1], John W. MacKenty[1], Vera Kozhurina-Platais[1], Susana E. Deustua[1], Derek Hammer[1], Tomas Dahlen[1], Elena Sabbi[1], Jennifer Mack[1], Sylvia M. Baggett[1]

1. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: WFC3 Team

The Wide Field Camera 3 (WFC3) is a fourth-generation UV/visible and IR imaging instrument on the Hubble Space Telescope (HST). Installed in May 2009, during HST servicing mission 4, both channels have been performing very well on-orbit. To provide optimum calibrated data, the WFC3 team routinely updates and refines the calibration software and associated files, designated as calibration products. We present some of the recently improved calibration products that will be of interest to current and future users of WFC3, including information on the chip-dependent zeropoints and flat fields, post-flash calibrations, and detector-to-image distortion corrections. The latter results in four new extensions (two per chip and dimension), in all UVIS FLTs retrieved from MAST after September 10, 2013. The D2IMFILE contains astrometric corrections for shifts of the raw X and Y positions induced by the lithographic-mask pattern. We discuss the migration of CALWF3 from the STSDAS package to HSTCAL, a package independent of IRAF; as a consequence, the IRAF/STSDAS version of CALWF3 is no longer being updated. Finally, we summarize recent improvements to aXe, a PyRAF/IRAF software package that enables automated extraction of spectra from WFC3 slitless spectral (grism) images. Updated versions of aXe are made available as part of the STSDAS testing environment (SSBX).

149.05 – A New, Deeper Long Baseline Study of ACS/WFC Extended Source CTE Effects

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Earlier attempts to perform this study on ACS/WFC observations of the original Hubble Deep Field taken early in the camera's history and comparing it to recent (circa 2011) observations of the same field were inconclusive due to insufficient S/N in the newer data. To remedy that problem and to study the effect with larger numbers and better statistics, we are now comparing original ACS/WFC data taken on the COSMOS field early in the camera's on-orbit lifetime with that of much more recent data on the COSMOS field taken as part of the CANDELS program. We also incorporate some newer techniques to better prepare the data for the automated CAS (in this case primarily Concentration and Asymmetry but not Clumpiness) morphological measurements. We describe these improved techniques, the measurements made, and the results obtained. Since CTE and these measurements involve the new standard pipeline CTE corrections and also involve shape, curvature, and displacement of objects, the results also may have implications for measurements of gravitational lensing in ACS/WFC fields, and especially the more subtle effects of gravitational weak lensing.

149.06 – ACS/WFC Geometric Distortion: a time dependency study

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We re-visit the issue of the time-dependency variation of the linear terms in the ACS/WFC geometric distortion. We performed a detailed photometric/astrometric study using F606W FLT and FLC images from the calibration field near globular cluster 47 Tucanae. We analyzed the time dependency of the linear terms by comparing individual observations with a standard catalog. A previous calibration of these drifts proved to be able to restore positions to the milli-arcsecond level for pre-SM4 data. We confirm this previously existing solution and we provide new and simple corrections for both FLT and FLC images that will allow observers to perform global astrometric studies with 0.02 WFC pixel precision using both pre- and post- SM4 images.

149.07 – Wide-field spatio-spectral interferometry for far-infrared space applications: A progress report

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The NASA Astrophysics Roadmap Committee adopted the far-IR community's vision and recommended far-IR interferometry as a needed capability in the 15 – 30 year time frame. The three major enabling technologies for such a mission are low-noise, high-speed detectors in small arrays; a demonstrated capability to cool optical system components to 4 K and focal planes to tens of mK with cryo-coolers; and the spatio-spectral interferometry ("double Fourier") technique through which wide-field integral field spectroscopic data are derived from interferometric measurements. This paper reports on the current status of wide-field spatio-spectral interferometry and plans for maturation of the technique to space-flight readiness. Relatively simple spatial-spectral test patterns have been observed with the Wide-Field Imaging Interferometry Testbed at NASA's Goddard Space Flight Center, and data cubes representing the observed scenes have been constructed based on the measured interferograms. A critical future milestone is the construction of an astronomically relevant, spatially and

spectrally complex scene.

149.08 – Technology Demonstration Milestone #1 for the EXoplanetary Circumstellar Environments and Disk Explorer (EXCEDE) II. Science Drivers and Implications.

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Contributing teams: EXCEDE Project Technology Development Team, HST GO 12228 Team

The EXoplanetary Circumstellar (CS) Environments and Disk Explorer (EXCEDE) is an EX class Explorer mission proposed to study the formation, evolution, architectures, and diversity of exoplanetary systems by characterizing suspected planet-hosting CS environments into and beyond host-star habitable zones using a small (0.7 m diameter) off-axis telescope. EXCEDE was selected by NASA (as a Class III Explorer program) for technology demonstration and maturation to advance key elements of its proposed starlight suppression system (SSS) combining the use of a Phase Induced Amplitude Apodized coronagraph, MEMS Deformable Mirror, closed-loop Low-Order Wavefront Sensing and Control, and mid-spatial frequency wavefront error correction and control using the science camera for electric field conjugation and speckle suppression for image contrast enhancement. To meet the science goals of the EXCEDE mission, the SSS must simultaneously, repeatably, and stably, deliver disk-to-starlight raw image contrast per resel of 1E-6 from 1.2 to 2 lambda/D, and 1E-7 from 2 to ~ 20 lambda/D in optical light, which has now been laboratory demonstrated for monochromatic light in an in-air environment (see paper I. by Belikov et al.) This level of performance when extended to 10% - 20% broadband light (technology demonstration milestone #2 to be pursued over the next year) will enable the EXCEDE mission. Here we discuss the applicability of these performance metrics to studying the current "here be dragons" regions of light-scattering CS debris disks, including those now well-observed as revealed at larger stellocentric angular distances with the Hubble Space Telescope Imaging Spectrograph's coronagraph with multiple-roll PSF-template subtracted coronagraphy as imaged in HST GO program 12228 in the context of the EXCEDE science mission goals. This investigation is funded in part by NASA grant NNX12AH39G, and STScI grant GO-12228.

149.09 – Developing Astrometric Drift Scans for the Spitzer Space Telescope

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We are currently developing and optimizing a new observing mode using the IRAC instrument on-board the Spitzer Space Telescope. The new method which uses a constant rate drift scan while the instrument collects data is based on the successful HST drift scan method for producing high astrometric precision (20 micro-arcsecond) parallaxes to improve the cosmological distance scale. The HST experience indicates that a factor of 10 improvement in astrometric precision is possible. Currently Spitzer astrometric precision is of order 20-40 milli-arcseconds per epoch. Increasing the precision by even a factor of three greatly facilitates studies of nearby brown dwarfs and increases our ability to measure parallaxes to these intrinsically faint and cool sources out to ~30 parsecs. Initial tests of the method with observations of NGC 2516 at 3.6 and 4.5 microns have shown that useful data are taken in drift scan mode and the scans are in the specified direction and rate. We have developed a tool to measure source centroids in the stacks of images taken while scanning. The tool groups the centroids into tracklets which can then be simultaneously fit to remove telescope jitter and instrumental distortion. We present our latest results in the analysis of this mode and the prospects for the scientific exploitation of this method. This

149.10 – Recent Results and Future Plans for the Gamma Ray Polarimeter Experiment (GRAPE)

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The Gamma RAy Polarimeter Experiment (GRAPE) is a balloon borne instrument designed for measuring the polarization of sources in the 50-500 keV energy range. It was first flown on a 26-hour balloon flight in the fall of 2011 from Ft. Sumner, NM. The GRAPE payload consists of an array of independent Compton polarimeter modules based on traditional scintillation technologies. The ultimate goal of our program is to operate GRAPE in a wide FoV configuration on a long duration balloon for the study of gamma-ray bursts. For the first balloon flight, however, GRAPE was configured in a collimated mode to facilitate observations of known point sources so that the polarization measurement capability of GRAPE could be demonstrated. The Crab nebula/pulsar, the active Sun, and Cygnus X-1 were the primary targets for the first flight. Although the Crab was detected, the polarization sensitivity was worse than expected, in part because of a lower-than-expected altitude for much of the flight. Only upper limits on the Crab polarization were obtained. Two M-class solar flares were also observed, with null results that indicate less than 30% polarization levels. This paper will describe the GRAPE payload, review the latest results from the first balloon flight, and present plans for the next GRAPE balloon flight, which is scheduled to take place in the fall of 2014 from Ft. Sumner, NM. The plans for 2014 involve several modifications designed to improve the polarization sensitivity to a level that would insure a measurement of the Crab polarization (assuming a polarization level consistent with that reported by INTEGRAL) and therefore a definitive demonstration of the capability of GRAPE to perform polarization measurements. The payload modifications include an expansion of the array of polarimeter modules from 16 to 24 and improvements to the instrument shielding. Sensitivity estimates of the resulting instrument, based on GEANT4 simulations, will be presented.

149.11 – The Speedster-EXD - A New Event-Triggered Hybrid CMOS X-ray Detector

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We report on the development of a new Teledyne Imaging Systems hybrid CMOS x-ray detector called the Speedster-EXD which is capable of event-triggered read-out. Hybrid CMOS detectors currently have many advantages over CCDs including lower susceptibility to radiation damage, lower power consumption, and faster read out time to avoid pile-up. In addition to these advantages, the Speedster-EXD has new in-pixel circuitry which includes CDS subtraction to reduce read noise and a CTIA amplifier to eliminate interpixel capacitance crosstalk. The new circuitry also includes an in-pixel comparator that triggers on x-ray events. The comparator feature allows the detector to only read pixels in which an x-ray is detected. This feature increases the detector array effective frame rate by orders of magnitude. The current advantages of hybrid CMOS x-ray detectors combined with the new in-pixel circuitry makes the Speedster-EXD an ideal candidate for future high throughput x-ray missions requiring large-format silicon imagers.

149.12 – New Worlds / New Horizons Science with an X-ray Astrophysics Probe

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In 2013 NASA commenced a design study for an X-ray Astrophysics Probe to address the X-ray science goals and program prioritizations of the Decadal Survey New World New Horizons (NWNH) with a cost cap of ~ $1B. Both the NWNH report and 2011 NASA X-ray mission concept study found that high-resolution X-ray spectroscopy performed with an X-ray microcalorimeter would enable the most highly rated NWNH X-ray science. Here we highlight some potential science topics,

namely: 1) a direct, strong-field test of General Relativity via the study of accretion onto black holes through relativistic broadened Fe lines and their reverberation in response to changing hard X-ray continuum, 2) understanding the evolution of galaxies and clusters by mapping temperatures, abundances and dynamics in hot gas, 3) revealing the physics of accretion onto stellar-mass black holes from companion stars and the equation of state of neutron stars through timing studies and time-resolved spectroscopy of X-ray binaries and 4) feedback from AGN and star formation shown in galaxy-scale winds and jets. In addition to these high-priority goals, an X-ray astrophysics probe would be a general-purpose observatory that will result in invaluable data for other NWNH topics such as stellar astrophysics, protostars and their impact on protoplanetary systems, X-ray spectroscopy of transient phenomena such as high-z gamma-ray bursts and tidal capture of stars by massive black holes, and searches for dark matter decay.

149.13 – High-contrast imager for Complex Aperture Telescopes (HiCAT): testbed design and coronagraph developments

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We present a new high-contrast imaging testbed designed to provide complete solutions for wavefront sensing and control and starlight suppression with complex aperture telescopes (NASA APRA; Soummer PI). This includes geometries with central obstruction, support structures, and/or primary mirror segmentation. Complex aperture telescopes are often associated with large telescope designs, which are considered for future space missions. However, these designs makes high-contrast imaging challenging because of additional diffraction features in the point spread function. We present a novel optimization approach for the testbed optical and opto-mechanical design that minimizes the impact of both phase and amplitude errors from the wave propagation of testbed optics surface errors. This design approach allows us to define the specification for the bench optics, which we then compare to the manufactured parts. We discuss the testbed alignment and first results. We also present our coronagraph design for different testbed pupil shapes (AFTA or ATLAST), which involves a new method for the optimization of Apodized Pupil Lyot Coronagraphs (APLC).

149.14 – X-ray Polarization Capabilities of the Gravity and Extreme Magnetism Small Explorer Mission Concept

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Contributing teams: GEMS team

Sensitive X-ray polarization measurements are now possible in a modest mission such as a NASA Small Explorer. We present the capabilities of the Gravity and Extreme Magnetism Small Explorer (GEMS) concept by presenting the top level and driving requirements and the key features of a design consistent with the technical constraints of the Small Explorer program. The design has progressed through Preliminary Design Review status and key performance characteristics of new technology elements (the Time Projection Polarimeters and the extendable optical bench) have been confirmed by measurement. Detailed models have demonstrated mission efficiency and background performance. Engineering designs support the concept with robust technical margins. An example of the broad observing program which could be achieved within 6 – 9 months (assuming estimated or required performance) is presented.

149.15 – Cosmic Ray Nuclei in the Fermi-LAT ACD

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The Anti-Coincidence Detector (ACD) of the Fermi Large Area Telescope (LAT) serves to identify charged particles, which cross the LAT at a rate orders of magnitude higher than that of the gamma-ray signal. We have developed a method that uses cosmic-ray nuclei, $Z > 3$, as a calibration source to improve charge resolution of the light deposit measurement in the ACD at high light levels. Improving the charge resolution of the ACD gives the LAT an additional tool for cosmic-ray nuclei charge discrimination and therefore enhances the LAT's capability for analysis of cosmic-ray nuclei. In this analysis, we are able to distinguish eight cosmic-ray nuclei: boron, carbon, nitrogen, oxygen, neon, magnesium, silicon and iron in the LAT ACD's

data. We present the results of our method, and demonstrate improved charge resolution for cosmic-ray nuclei in the ACD.

149.16 – Scientific Implications of the Modified Observing Strategy of the Fermi Gamma-ray Space Telescope

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Contributing teams: Fermi-LAT Collaboration, Fermi-GBM team

Near the end of 2013 the Fermi Gamma-ray Space Telescope (Fermi) mission plans to change to a modified observing strategy designed to favor the Galactic center while maintaining full sky-survey capabilities. This change would have important implications for the science of the Fermi Large Area Telescope (Fermi-LAT). In particular, this change will 1) substantially increase the Fermi-LAT sensitivity to young pulsars in the inner Galaxy, 2) provide simultaneous observations of the Galactic center with a suite of other instruments that have extended observing campaigns of the expected disruption of the G2 gas cloud complex (see https://wiki.mpe.mpg.de/gascloud/ProposalList) , 3) double the rate of improvement of statistical power for of searches for spectral lines from the Galactic center. In this contribution we discuss these topics. We also investigate ways in which the modified observing strategy can induce systematic biases, and discuss how those biases can be studied and mitigated with studies of control samples of LAT data.

149.17 – ACCESS: Detector Control and Performance

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ACCESS, Absolute Color Calibration Experiment for Standard Stars, is a series of rocket-borne sub-orbital missions and ground-based experiments that will enable improvements in the precision of the astrophysical flux scale through the transfer of absolute laboratory detector standards from the National Institute of Standards and Technology (NIST) to a network of stellar standards with a calibration accuracy of 1% and a spectral resolving power of 500 across the 0.35 to 1.7 micron bandpass (companion poster, Kaiser et al.). The flight detector and detector spare have been selected and integrated with their electronics and flight mount. The controller electronics have been flight qualified. Vibration testing to launch loads and thermal vacuum testing of the detector, mount, and housing have been successfully performed. Further improvements to the flight controller housing have been made. A cryogenic ground test system has been built. Dark current and read noise tests have been performed, yielding results consistent with the initial characterization tests of the detector performed by Goddard Space Flight Center's Detector Characterization Lab (DCL). Detector control software has been developed and implemented for ground testing. Performance and integration of the detector and controller with the flight software will be presented. NASA APRA sounding rocket grant NNX08AI65G supports this work.

149.18 – ACCESS: Thermal Mechanical Design, Performance, and Status

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Systematic errors associated with astrophysical data used to probe fundamental astrophysical questions, such as SNeIa

observations used to constrain dark energy theories, are now rivaling and exceeding the statistical errors associated with these measurements. ACCESS: Absolute Color Calibration Experiment for Standard Stars is a series of rocket-borne sub-orbital missions and ground-based experiments designed to enable improvements in the precision of the astrophysical flux scale through the transfer of absolute laboratory detector standards from the National Institute of Standards and Technology (NIST) to a network of stellar standards with a calibration accuracy of 1% and a spectral resolving power of 500 across the 0.35 1.7μm bandpass. Achieving this level of accuracy requires characterization and stability of the instrument and detector including a thermal background that contributes less than 1% to the flux per resolution element in the NIR. We will present the instrument and calibration status with a focus on the thermal mechanical design and associated performance data. The detector control and performance will be presented in a companion poster (Morris, et al). NASA APRA sounding rocket grant NNX08AI65G supports this work.

149.19 – Characterization of Si Hybrid CMOS Detectors for use in the Soft X-ray Band

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In a joint program between Penn State University and Teledyne Imaging Sensors a soft X-ray detector based on the HAWAII Hybrid Si CMOS detector (HCD) has been developed. HCDs could potentially be the optimum detectors for the next generation of X-ray missions, especially those with focused optics and/or large effective area. These innovative detectors are active pixel sensors (APS) which allow a pixel to be read through individual in-pixel electronics, without the need to transfer charge across many pixels, in contrast to a CCD. They are made by bonding a Si absorbing layer to a pixelated CMOS readout, allowing the two layers to be optimized independently. The advantages of this design compared to CCDs are high speed timing (~100 μs in full imaging mode), a flexible windowed readout to reduce pile-up, dramatically improved radiation hardness and resistance to micrometeoroid damage, and reduced power requirements. We present recent measurements of energy resolution, read noise, inter-pixel crosstalk, quantum efficiency, and dark current for four of these devices.

149.20 – Enhanced Fluoride Over-coated Al Mirrors for FUV Space Astronomy

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Astronomical observations in the Far Ultraviolet (FUV) spectral region are some of the more challenging due to the very distant and faint objects that are typically searched for in cosmic origin studies such as origin of large scale structure, the formation, evolution, and age of galaxies and the origin of stellar and planetary systems. These challenges are driving the need to improve the performance of optical coatings over a wide spectral range that would increase reflectance in mirrors and reduced absorption in dielectric filters used in optical telescope for FUV observations. This paper will present recent advances in reflectance performance for Al+MgF2 mirrors optimized for Lyman-alpha wavelength by performing the deposition of the MgF2 overcoat at elevated substrate temperatures. We will also present optical characterization of little studied rare-earth fluorides such as GdF3 and LuF3 that exhibit low-absorption over a wide wavelength range and could therefore be used as high refractive index alternatives for dielectric coatings at FUV wavelengths.

149.21 – Investigation of the Back-reflection from an On-axis Telescope for Space-based Gravitational Wave Detectors

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The Laser Interferometer Space Antenna (LISA) represents a class of proposed space-based gravitational wave detectors that will operate in the frequency band between 0.1 mHz and 1 Hz. These missions are characterized by a triangular constellation of three spacecraft (SC), separated by gigameters, in a heliocentric orbit. A reflecting telescope will transfer the laser signals between the SC, and laser interferometry is used to measure length changes between proof masses housed on adjacent SC with pm/rtHz sensitivity. Even though LISA is used as the reference, the principles of this study can be applied to any space-based gravitational wave mission that uses reflecting telescopes to exchange laser signals between SC. One of the proposed telescopes uses a classical Cassegrain design with the secondary mirror axially aligned to the primary mirror. Back-reflected light from the secondary can introduce phase noise to the measurement signal due to length changes between the telescope structure and the optical bench. This phase noise must be suppressed below 1 μrad/rtHz to meet the LISA requirements. We derived a set of requirements for the mode-matched power in the back-reflected field that scale with the stability of the optical pathlength between the telescope and the optical bench. Simulations have demonstrated that the back-reflected power can be sufficiently attenuated by using a specifically patterned anti-reflective (AR) region at the center of the secondary mirror. After pursuing a wide variety of shapes for the AR region we have settled on three candidates to further investigate and optimize. Several prototype secondaries have been manufactured with a patterned AR region and are

currently undergoing experimental testing.

149.22 – Astrometry with small-size collapsible space telescope

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Imaging astrometry is a powerful scientific tool for a wide variety of science cases, such us galactic dynamics, cluster membership determination, parallaxes and exoplanet detection and characterization. In order to reach the astrometric accuracy required to enable these science cases, time-varying distortions should be calibrated. We propose to implement a diffractive pupil to calibrate the telescope plate scale and maximize the astrometric accuracy for a given aperture size. This approach was tested and validated in the laboratory. In this paper, we present the plan to implement the diffractive pupil on a small 6" collapsible space telescope that is under development at NASA Ames Research Center. This project will demonstrate new efficient spacecraft packing technologies for cost-effective deployment of small-scale imaging telescopes. Adding the diffractive pupil to this telescope will allow increasing the Technology Readiness Level of this technology, enabling its application on larger astrophysics missions, such as WFIRTS. We plan to perform giant exoplanet characterization and detection with this telescope.

149.23 – Lightweight ZERODUR®: A Candidate Material for Affordable Future UVOIR Space Telescopes of All Apertures

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Recent Developments now make available for spaceborne applications highly lightweighted mirrors in ZERODUR®, regarded to be the "gold standard" material for thermal stability. ZERODUR® has flown on over 30 missions, including two great observatories, but not previously to this high degree of lightweighting. Now highly lightweighted mirror substrates can be made from a single billet of low expansion glass which exhibits remarkably low thermal expansion, anisotropy and inhomogeneity. This staility has the potential to simplify every aspect of a mission payload cost. A 1.2m open-back isogrid lightweighted mirror substrate has been made by SCHOTT exhibiting 88% lightweighting and a first Eigenfrequency over 200Hz. Also a recently made 0.3m isogrid lightweighted mirror exhibits ribs thinner than 0.9mm. Mirror or mirror segment substrates can be cost-effectively manufactured from monolithic blanks in apertures as small as 0.3m aperture to over 4m aperture (until recently SCHOTT maintained a line to make 8m ZERODUR® billets). We will describe this technology, the attributes of isogrid lightweighted mirror blanks, and the relevance of this material and manufacturing approach to upcoming UVOIR missions from suborbital to Explorer class to next generation Great Observatory. Lightweight ZERODUR® supports optical telescope systems requiring great stability, even in the presence of payload and scene thermal perturbations. Furthermore, mirrors or mirror segments made with the approach described can be made to remarkably short schedule, cost effectively and with little risk.

149.24 – Improved Characterization of the HST/STIS CCD

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The CCD on board Hubble's Space Telescope Imaging Spectrograph (STIS) has been accumulating radiation damage on-orbit for nearly 17 years, resulting in increased dark rate, increased accumulation of hot pixels, and decreased charge transfer efficiency (CTE). In order to mitigate the growth of hot pixels, STIS performs monthly anneals, warming the detector for approximately 12 hours. We report improved characterization of the STIS CTE using recent darks taken with multiple readout amplifiers. Furthermore, we present preliminary results using the STIS pixel-based CTE correction to better characterize CCD dark rate and annealing efficacy. By reducing CTE trails when processing darks, we are able to more accurately identify hot pixels before and after each anneal. Likewise, the mode of the dark rate can be more accurately measured, leading to a reduction of approximately 35% from its uncorrected value. This will eventually lead to improved removal of dark current and hot pixels in science observations, yielding improved S/N. These improved characterizations will also assist with observation planning that more accurately reflects upcoming improvements to data reduction. We also report on the behavior of the STIS CCD when exposed beyond the full well limit of individual pixels. As an individual pixel is saturated, any excess electrons tend to bleed along the columns, i.e., in the direction of the parallel shifts. For observations taken near the central rows of the detector the total number of electrons in each column can usually be recovered to a very high degree of accuracy. This allows high S/N observations to be obtained well beyond the level at which an individual pixel saturates. However, it has recently been realized that detector regions close to the serial readout can behave differently when saturated, and image artifacts in the form of trails in the serial direction can appear. We discuss the circumstances under which these artifacts occur and the implications for interpretation and analysis of affected data.

149.25 – Update to the Cosmic Origins Spectrograph FUV Calibration: Improved Characterization Below 1150 Angstroms and Improved Absolute Flux Calibration at all Wavelengths.

Paule Sonnentrucker[1], K. A. Bostroem[1], Justin Ely[1], John H. Debes[1], Audrey DiFelice[1], Svea Hernandez[1], Philip E. Hodge[1], Kevin Lindsay[1], Sean A. Lockwood[1], Derck Massa[1], Cristina M. Oliveira[1], Julia Roman-Duval[1], Steven V. Penton[1], Charles R. Proffitt[1, 2], Joanna M. Taylor[1]
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As of Cycle 20, the three COS/FUV "Blue Mode" wavelength settings at G130M/1055, 1096 and 1222, have become available as regular observing modes. We provide updates on the wavelength and flux calibration of these new Blue Mode settings, which allow medium-resolution spectroscopy down to 900A with effective areas comparable to those of FUSE. We discuss also recent improvements to the COS/FUV flux and flat-field calibrations and present the most recent time-dependent sensitivity trends of the FUV and NUV channels.

149.26 – A New HST FGS Astrometry Capability

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A new HST FGS Astrometry capability is available and was tested on-orbit. This new observing mode employs a series of grids, each composed of 351 x 351 horizontal and vertical steps , offset in such as way as to densely sample the 2-dimensional intensity profile of the collimated beam of a point source over the 5x5 arc second instantaneous field of view (IFOV) of the FGS. Observations have been executed to observe Beta Lupe with the F5ND filter and HD209458 with the F583W and Pupil filters. This calibration supports the construction of models needed to analyze FGS Transfer mode science data for widely separated binary systems and for observations that have more than one or two objects in the IFOV. Preliminary results using this new calibration will be demonstrated on a binary system with a third-light source present in the beam.

149.27 – Solar System Science with HST and JWST: Connecting the Past, Present, and Future

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NASA's Great Observatories have long provided solar system scientists with unique imaging and spectroscopic capabilities which have resulted in many important discoveries. As a successor to the Hubble Space Telescope (HST), the James Webb Space Telescope (JWST) will also make valuable contributions to solar system research. This poster summarizes some of HST's key past contributions to solar system science such as SL9, Pluto and its moons, and KBOs. Highlights of current HST solar system observing (e.g. Comet ISON) are presented; and finally, examples of future JWST observations are presented with an emphasis on how JWST will extend and improve on what HST has done.

149.28 – Simulations of MIRI Four-Quadrant Phase Mask Coronagraphy

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The Mid-Infrared Instrument (MIRI) on JWST is equipped with four-quadrant phase mask coronagraphs (4QPM) that will enable cutting-edge science at small inner working angles. The effectiveness of these phase masks relies on accurate target acquisition and positioning at the apex of the four quadrants. In order to optimize MIRI target acquisition as well as coronagraphy operations in general, we have run optical simulations to derive contrast performances of all three MIRI 4QPM for various slew accuracy models. Our simulations include full Fourier propagation from the pupil entrance to MIRI focal plane, including intervening masks, realistic wavefront error, transmission profiles for filters and Germanium coating, as well as detector efficiency. We also include photon noise from the star and background as well as detector noise (readout, pixel-to-pixel variations). Here, we discuss the use of the CCC mechanism and the impact of latent images on science. Our results suggest that operations of MIRI coronagraphs should be modified to allow for cases where the CCC is not to be used. This work will also tie in the implementation of coronagraphy in the JWST Exposure time Calculator. _____

149.29 – Overview and status of the JWST science instrument payload

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Contributing teams: The JWST ISIM Team, The JWST Science Working Group

The James Webb Space Telescope (JWST) Integrated Science Instrument Module (ISIM) is the science instrument payload of the JWST. It is one of three system elements that comprise the JWST space vehicle and consists of four science sensors, a fine guidance sensor, and nine other systems. At 1.4 metric tons, it comprises approximately 20% of the JWST mass. The ISIM began its first space simulation test during August which is the first element-level test in the JWST Program. In this poster, we present an overview of the ISIM and its status.

149.30 – James Webb Space Telescope Synergy with Dark Energy Missions

Jonathan P. Gardner[1]
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As the successor to the Hubble Space Telescope (HST), the James Webb Space Telescope (JWST) will be a general-purpose observatory which will impact all areas of observational astronomy. Two future dark energy missions are being planned: Euclid in Europe and the Wide-Field Infrared Survey Telescope (WFIRST) in the US. While JWST is designed to go very deep in the infrared, the dark energy missions will conduct wide-area surveys of a substantial fraction of the sky in the optical and near-infrared. Synergy between JWST and Euclid or WFIRST could proceed in several ways. (1) JWST will make contributions to dark energy science that will be complementary to the results from the wide-area surveys. These contributions could include a more precise measurement of the current value of the Hubble constant, and rest-frame near-infrared light curves for high-redshift type Ia supernovae. (2) JWST could directly contribute to the dark energy science of the wide-area missions by providing additional calibration, investigating anomalies in the dataset, or with complementary observations that are deeper over a smaller area. (3) JWST could make follow-up observations of Euclid or WFIRST discoveries of rare objects, such as high-redshift quasars, strong-lens systems, galaxy clusters and supernovae.

149.31 – Status of the James Webb Space Telescope Observatory

Mark Clampin[1], Charles W. Bowers[1]
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The James Webb Space Telescope (JWST) is a large aperture (6.5 meter), cryogenic space telescope with a suite of near and mid-infrared instruments covering the wavelength range of 0.6 μm to 28 μm. JWST's primary science goal is to detect and characterize the first galaxies. It will also study the assembly of galaxies, star formation, and the formation of evolution of planetary systems. Significant progress has been made in the development of the observatory during the past year with preparations for the Spacecraft Element Critical Design Review, completion of the telescope backplane, delivery of flight mirrors to the Goddard Space Flight Center, and testing of the template membranes for the sunshield. JWST will be reviewed in the context of initial performance measurements of flight hardware, and performance projections from integrated system models of the observatory.

149.32 – Solar System Observing Capabilities With The James Webb Space Telescope

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The James Webb Space Telescope (JWST) will provide important new capabilities to study our Solar System. JWST is a large aperture, cryogenic, infrared-optimized space observatory under construction by NASA, ESA, and CSA for launch in 2018 into a L2 orbit. Imaging, spectroscopy, and coronography covers 0.6-29 microns. Integral-field spectroscopy is performed with apertures 3 to 7 arcsec square (spatial slices of 0.1 to 0.6 arcsec). JWST is designed to observe Solar System objects having apparent rates of motion up to 0.030 arcseconds/second. This tracking capability includes the planets, satellites, asteroids, Trans-Neptunian Objects, and comets beyond Earth's orbit. JWST will observe in the solar elongation range of 85 to 135 degrees, and a roll range of +/-5 degrees about the telescope's optical axis. During an observation of a moving target, the science target is held fixed in the desired science aperture by controlling the guide star to follow the inverse of the target's trajectory. The pointing control software uses polynomial ephemerides for the target generated using data from JPL's HORIZON system. The JWST guider field of view (2.2x2.2 arcmin) is located in the telescope focal plane several arcmin from the science apertures. The instrument apertures are fixed with respect to the telescope focal plane. For targets near the ecliptic, those apertures also have a nearly fixed orientation relative to the ecliptic. This results from the fact that the Observatory's sunshield and solar panels must always be between the telescope and the Sun. On-board scripts autonomously control the execution of the JWST science timeline. The event-driven scripts respond to actual slew and on-board command execution, making operations more efficient. Visits are scheduled with overlapping windows to provide execution flexibility

and to avoid lost time. An observing plan covering about ten days will be uplinked weekly. Updates could be more frequent if necessary (for example, to accommodate a Target of Opportunity - TOO). The event-driven operations system supports time-critical observations and TOOs. The minimum response time for TOOs is 48 hours (observation approval to execution).

149.33 – Providing user guidance for the Micro-Shutter Array Planning Tool for JWST/NIRSpec

David R. Soderblom[1], Diane M. Karakla[1], Tracy L. Beck[1], Gary Curtis[1], Alexander Shyrokov[1], Karla Peterson[1], William P. Blair[1], Jeff A. Valenti[1]
1. STScI, Baltimore, MD, United States.
Contributing teams: STScI NIRSpec team

The Micro-Shutter Arrays (MSAs) in the Near-Infrared Spectrograph for JWST provide the means to obtain spectra of ~100 objects at once. However, achieving that level of multiplexing requires sufficient candidates within the NIRSpec field of view, high quality astrometry for those candidates, and software that can identify effective solutions, given all the constraints and observing requirements. That software – the MSA Planning Tool, or MPT – is complex, yet there must be effective user guidance so that astronomers can plan the details of their observations and can understand quantitatively what will be achieved, all in a way that can be executed without the need for later modifications. This contribution describes the strategy and procedures we are adopting to enable users to use the MPT.

149.34 – Planning JWST/NIRSpec Multi-Object Spectroscopy: Galaxy Kinematics at Redshifts 2-3

Susan A. Kassin[1], Tracy L. Beck[1], Diane M. Karakla[1], David R. Soderblom[1]
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The JWST Near-Infrared Spectrograph (NIRSpec) team at STScI is developing software to plan observations with one of the most important and complex modes on JWST, namely the Micro-Shutter Array (MSA). Here we present an example of planning a complex observing scenario with the MSA: multi-position angle slit spectra of a large sample of galaxies at redshifts 2-3. The science goal is to discern their internal gas kinematics. At high redshift, galaxy morphologies are likely to be disturbed and the merger rate high, ensuring that major axes (if galaxies even have any) will be difficult to ascertain. A multi-position angle strategy is needed to ensure that at least one slit is placed close enough to the galaxies' major axes to detect any rotation. Here we investigate the use of multiple position angles in planning an example survey of galaxy kinematics.

149.35 – Algorithms for Planning Multi-Object Spectroscopy Observations with the JWST Near-Infrared Spectrograph

Diane M. Karakla[1], Klaus Pontoppidan[1], Alexander Shyrokov[1], Tracy L. Beck[1], Jeff A. Valenti[1], David R. Soderblom[1], Jason Tumlinson[1], James Muzerolle[1]
1. STScI, Baltimore, MD, United States.

Planning observations for the JWST NIRSpec Multi-Object Spectroscopy will be complex because of the fixed-grid nature of the Micro-Shutter Arrays (MSAs) used for this instrument mode. Two algorithms have been incorporated into the 'MSA Planning Tool' (MPT) in the Astronomers Proposal Tools (APT) for this NIRSpec observation planning process. The 'Basic Algorithm' and the 'Constrained Algorithm' both determine a set of on-sky pointing positions which yield an optimal number of science sources observed per MSA shutter configuration, but these algorithms have different strategies for generating their observing plans. The Basic algorithm uses a defined set of fixed dithers specified by the observer, while the Constrained algorithm can more flexibly define dithers by merely constraining offsets from one pointing position to the next. Each algorithm offers advantages for different observing cases. This poster describes the two algorithms and their products, and clarifies observing cases where clear planning advantages are offered by each.

149.36 – First Cryo-Vacuum Test of the JWST Integrated Science Instrument Module

Randy A. Kimble[1], Scott R. Antonille[1], Vicki Balzano[2], Brian J. Comber[3, 1], Pamela S. Davila[1], Michael D. Drury[4, 1], Alistair Glasse[5], Stuart D. Glazer[1], Ray Lundquist[1], Steven D. Mann[6, 1], Douglas B. McGuffey[1], Kevin J. Novo-Gradac[7, 1], Konstantin Penanen[8], Deborah D. Ramey[7, 1], Joseph Sullivan[9], Julie Van Campen[7, 1], Maria B. Vila[10]
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United States. 5. UK Astronomy Technology Centre, Edinburgh, United Kingdom. 6. Hammers Company, Greenbelt, MD, United States. 7. Stinger Ghaffarian Technologies, Greenbelt, MD, United States. 8. Jet Propulsion Laboratory, Pasadena, CA, United States. 9. Ball Aerospace and Technologies Corporation, Boulder, CO, United States. 10. Com Dev International, Ottawa, ON, Canada.

The integration and test program for the Integrated Science Instrument Module (ISIM) of the James Webb Space Telescope (JWST) calls for three cryo-vacuum tests of the ISIM hardware. The first is a risk-reduction test aimed at checking out the test hardware and procedures; this will be followed by two formal verification tests that will bracket other key aspects of the environmental test program (e.g. vibration and acoustics, EMI/EMC). The first of these cryo-vacuum tests, the risk-reduction test, was executed at NASA's Goddard Space Flight Center starting in late August, 2013. Flight hardware under test included two (of the eventual four) flight instruments, the Mid-Infrared Instrument (MIRI) and the Fine Guidance Sensor/Near-Infrared Imager and Slitless Spectrograph (FGS/NIRISS), mounted to the ISIM structure, as well as the ISIM Electronics Compartment (IEC). The instruments were cooled to their flight operating temperatures (~40K for FGS/NIRISS, ~6K for MIRI) and optically tested against a cryo-certified telescope simulator. Key goals for the risk reduction test included: 1) demonstration of controlled cooldown and warmup, stable control at operating temperature, and measurement of heat loads, 2) operation of the science instruments with ISIM electronics systems at temperature, 3) health trending of the science instruments against instrument-level test results, 4) measurement of the pupil positions and six degree of freedom alignment of the science instruments against the simulated telescope focal surface, 5) detailed optical characterization of the NIRISS instrument, 6) verification of the signal-to-noise performance of the MIRI, and 7) exercise of the Onboard Script System that will be used to operate the instruments in flight. In addition, the execution of the test is expected to yield invaluable logistical experience – development and execution of procedures, communications, analysis of results – that will greatly benefit the subsequent verification tests. At the time of this submission, the hardware had reached operating temperature and was partway through the cryo test program. We report here on the test configuration, the overall process, and the results that were ultimately obtained.

149.37 – The Planning Process for Multi-Object Spectroscopy with the JWST Near-Infrared Spectrograph

Tracy L. Beck[1], Diane M. Karakla[1], Alexander Shyrokov[1], Klaus Pontoppidan[1], David R. Soderblom[1], Jeff A. Valenti[1], Susan A. Kassin[1], Karoline Gilbert[1], William P. Blair[1], James Muzerolle[1], Jason Tumlinson[1], Charles D. Keyes[1], Cheryl M. Pavlovsky[1], Thompson LeBlanc[1]
1. Space Telescope Science Institute, Baltimore, MD, United States.

The Near-Infrared Spectrograph (NIRSpec) for the James Webb Space Telescope (JWST) will have a powerful multi-object spectroscopy mode using four configurable Micro-Shutter Arrays (MSAs). The contiguous MSA shutters can be opened to form slits on astronomical targets, for simultaneous spectroscopy of up to 100 sources per exposure. The NIRSpec MSA shutters are in a fixed grid pattern, and careful analysis in the observation planning process will be crucial for optimal definition of science exposures. Our goal is to maximize the number of astronomical science sources observed in the fewest number of MSA slit configurations. We are developing algorithms in the NIRSpec MSA Planning Tool (MPT) to improve the quality of planned observations using several common science observing strategies as test use cases. For example, the needs for planning extremely deep exposures on a small number of JWST discovered z > 10 galaxy candidates will differ significantly from the requirements for planning spectral observations on a representative sample of stars from a galactic star cluster catalog. In this poster, we present a high level overview of our plans to develop and optimize the MPT for the JWST NIRSpec multi-object spectroscopy mode.

149.38 – Imaging Polarimetry With Polarization-Sensitive Focal Planes

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We present a compact, lightweight, snapshot imaging polarimeter designed for operation in the near-infrared (NIR) and mid-infrared (MIR). Flux, polarization and spectral energy distribution are the fundamental measurements through which we infer properties of the sources of radiation such as intensity, temperature, chemical composition, emission mechanisms and structure. In recent decades, many scientific fields that utilize radiometry and spectroscopy have benefited from revolutionary improvements in instrumentation, for example, charge-coupled devices, hybridized infrared arrays, multi-object spectrometers and adaptive optics. Advances in polarimetric instrumentation have been more modest. Recently, the fabrication of microgrid polarizer arrays (MGPAs), facilitated the development of polarization-sensitive focal planes. These devices have inherent capability to measure the degree and angle of polarization across a scene (i.e., imaging polarimetry) instantaneously, without the need for multiple exposures and moving optics or multiple detectors. MGPA-based devices are compact, lightweight, and mechanically robust and perfectly suited for deployment on space-based and airborne platforms. We describe the design, operation and expected performance of MGPA-based imaging polarimeters and identify the applications for which these polarimeters are best suited.

149.39 – New and Better H2RG Detectors for the JWST Near Infrared Spectrograph

Bernard J. Rauscher[1]
1. NASA's GSFC, Greenbelt, MD, United States.

Remanufacturing of the near-infrared H2RG detectors for the James Webb Space Telescope (JWST) is nearing completion. The first of the Near Infrared Spectrograph (NIRSpec) flight candidates were delivered on-schedule this summer. We tested the detectors at Teledyne and characterized them in the Goddard Detector Characterization Laboratory (DCL), with excellent agreement between the two labs. Here we describe the DCL results which show the new detectors to be even better than the previous flight detectors. Highlights include improvements in the transimpedance gain that will reduce read noise and generally excellent QE over the full bandpass.

149.40 – ISS-Lobster

Jordan Camp[1], Scott D. Barthelmy[1], Robert Petre[1], Neil Gehrels[1], Francis E. Marshall[1], Judith L. Racusin[1], Andrew Ptak[1]
1. NASA / Goddard Space Flight Center, Greenbelt, MD, United States.

This poster presents ISS-Lobster, a wide-field X-ray transient mission proposed to be deployed on the International Space Station. Through its unique imaging X-ray optics that allow a 30 deg by 30 deg FoV, a 1 arc min position resolution and a 10^-11 erg/(sec cm2) sensitivity in 2000 sec, ISS-Lobster will observe numerous events per year of X-ray transients related to compact objects, including: tidal disruptions of stars, supernova shock breakouts, neutron star bursts and superbursts, high redshift Gamma-Ray Bursts, and perhaps most exciting, X-ray counterparts of gravitational wave detections involving both stellar mass and supermassive black holes. A 3-axis gimbal system will allow fast pointing in response to any independent, multi-wavelength indication of these events. Finally, deployment of this detector on the ISS will realize significant cost savings compared to a free-flying satellite as power, communication, and ISS transport are provided.

149.42 – H4RG Near-IR Detectors with 10 micron pixels for WFIRST and Space Astrophysics

Jeffrey W. Kruk[1], Bernard J. Rauscher[1]
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Hybrid sensor chip assemblies (SCAs) employing HgCdTe photo-diode arrays integrated with CMOS read-out integrated circuits (ROICs) have become the detector of choice for many cutting-edge ground-based and space-based astronomical instruments operating at near infrared wavelengths. 2Kx2K arrays of 18-micron pixels are in use at many ground-based observatories and will fly on JWST and Euclid later this decade. The Wide-Field Infra-Red Survey Telescope (WFIRST) mission, which will survey large areas of the sky with reasonably-fine sampling, is extending these prior designs by developing 4Kx4K HgCdTe NIR hybrid detectors with 10 micron pixels. These will provide four times as many pixels as the current 2Kx2K detectors in a package that is only slightly larger. Four prototype 4Kx4K devices with conservative pixel designs were produced in 2011; these devices met many though not all WFIRST performance requirements. A Strategic Astrophysics Technology proposal was submitted to further the development of these detectors. This poster describes the technology development plan, progress made in the first year of the program, and plans for the future.

150 – AGN, QSO, Blazars Poster Session III

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

150.01 – Imaging Redshift Estimates for Fermi BL Lacs

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We have measured i'' images of BL Lacertae objects (BL Lacs) to detect or constrain the flux of the host galaxy. Under common standard candle assumptions these data provide estimates of or lower bounds on the redshift. Our targets are a set of flat-spectrum radio counterparts of high flux Fermi Large Area Telescope (LAT) sources, with deep spectral observations showing them to be continuum-dominated BL Lacs. Host galaxies were detected by fitting the imaging data from each object to a variable model of a BL Lac consisting of a point source AGN and a galaxy profile. In this sample 6 of 11 BL Lacs yielded significant host detections, with standard candle redshifts z=0.10-0.66. These, and the remaining lower bounds are in good agreement with other redshifts estimates for these sources.

150.02 – The <I>XMM-Newton</I> View of Weak Emission-Line Quasars

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The Sloan Digital Sky Survey discovered a remarkable set of quasars at $z = 2.2$ 5.9 having extremely weak rest-frame UV emission lines in their spectra (hereafter, WLQs). One hypothesis explaining the extreme weakness of their emission lines is that WLQs are high accretion rate sources, and one manifestation of a high accretion rate is a steep hard-X-ray spectral slope. We therefore performed spectral analysis of all the high-quality X-ray observations of WLQs available in the archive. This analysis includes new *XMM-Newton* observations of SDSS J0928+1848 and SDSS J1231+0138, at $z = 3.8$ and $z = 3.2$ respectively, alongside the spectral analysis of two archival *XMM-Newton* sources, SDSS J1141+0219 and SDSS J1012+5313, at $z = 3.6$ and $z = 3.0$ respectively. With a total exposure time of ?78 ks and an average of ?1200 counts per source, we derived the hard-X-ray photon index for each object, as well as the mean photon index derived from joint-fitting these spectra, while accounting for the possibility of intrinsic absorption for which we found no evidence. Our results show that the mean photon index of the four WLQs is below the average observed in luminous radio-quiet quasars, consistent with the fact that all of the WLQs in the *XMM-Newton* archive are radio intermediate. This is mainly a consequence of selecting the X-ray brightest WLQs for *XMM-Newton* observations. In order to be able to test the hypothesis that WLQs have high accretion rates, future *XMM-Newton* observations should target radio-quiet WLQs, and suitable candidates likely lie at lower redshifts, i.e. at $z < 2.2$.

150.03 – Bayesian Multiscale Analysis of X-Ray Jet Features in High Redshift Quasars

Kathryn McKeough[1], Aneta Siemiginowska[2], Vinay Kashyap[2], Nathan Stein[3]
1. Carnegie Mellon University, Pittsburgh, PA, United States. 2. Harvard- Smithsonian Center for Astrophysics, Boston, MA, United States. 3. Harvard University, Boston, MA, United States.

X-ray emission of powerful quasar jets may be a result of the inverse Compton (IC) process in which the Cosmic Microwave Background (CMB) photons gain energy by interactions with the jet's relativistic electrons. However, there is no definite evidence that IC/CMB process is responsible for the observed X-ray emission of large scale jets. A step toward understanding the X-ray emission process is to study the Radio and X-ray morphologies of the jet. We implement a sophisticated Bayesian image analysis program, Low-count Image Reconstruction and Analysis (LIRA) (Esch et al. 2004; Conners & van Dyk 2007), to analyze jet features in 11 Chandra images of high redshift quasars (z ~ 2 - 4.8). Out of the 36 regions where knots are visible in the radio jets, nine showed detectable X-ray emission. We measured the ratios of the X-ray and radio luminosities of the detected features and found that they are consistent with the CMB radiation relationship. We derived a range of the bulk lorentz factor (?) for detected jet features under the CMB jet emission model. There is no discernible trend of ? with redshift within the sample. The efficiency of the X-ray emission between the detected jet feature and the corresponding quasar also shows no correlation with redshift. This work is supported in part by the National Science Foundation REU and the Department of Defense ASSURE programs under NSF Grant no.1262851 and by the Smithsonian Institution, and by NASA Contract NAS8-39073 to the Chandra X-ray Center (CXC). This research has made use of data obtained from the Chandra

150.04 – The Impact of Gamma-ray Halos on the Angular Anisotropy of the Extragalactic Gamma-ray Background

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1. Goddard Space Flight Center, Greenbelt, MD, United States. 2. University of Crete, Heraklion, Crete, Greece.

The study of the development of electromagnetic cascades in intergalactic magnetic fields (IGMF) serves as a robust probe into the strength and structure of these magnetic fields. Charged particles in electromagnetic cascades are deflected by magnetic fields giving rise to gamma-ray halos around extragalactic sources of VHE gamma rays (e.g., BL Lacertae-type objects). Such gamma-ray halos can have a profound impact on the intensity and angular properties of the contribution of extragalactic VHE sources to the extragalactic gamma-ray background (EGB) as measured by the Fermi-LAT at GeV energies. We demonstrate the impact of the deflection of cascades by the IGMF on the collective spectrum of extragalactic VHE sources, as well as the impact on the angular anisotropy of the EGB as a function of energy.

150.05 – The Largest X-ray Selected Sample of <i>z</i> > 3 AGNs: C-COSMOS + ChaMPS

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There is strong evidence that powerful active galactic nuclei (AGNs) are important to the evolution of galaxies. AGN evolution at high redshifts, before the density peak, illuminates the role of AGN in the formation and co-evolution of galaxies and their central supermassive black holes (SMBHs) when rapid SMBH growth took place. Optical surveys (e.g. Glikman et al. 2011; Ikeda et al. 2011) are severely biased against obscuration. In contrast, X-ray surveys detect obscured AGNs up to Compton Thick and are now sensitive enough to sample the bulk of the $z > 3$ AGN population. The few X-ray studies to date suggest a significant decline at $z > 3$ (e.g. Brusa et al. 2009; Civano et al. 2011; Vito et al; 2012), but the shape of this decline is still uncertain due to the limited sample size, especially at $z > 4$. To overcome these limits, we combined the two largest samples of $z > 3$ X-ray selected AGN with spectroscopic redshifts: the Chandra Multi-wavelength Project (ChaMP) survey (Trichas et al. 2012), and the C-COSMOS survey (Civano et al. 2011). The total of 159 $z > 3$ AGNs almost doubles the sample size and, most importantly, triples the sample at $z > 4$, where the uncertainties have been greatest. Our sample includes ~35 sources in the low luminosity range [$L_X < 10^{44}$ erg/s] which gives a first determination of their density evolution. Our sample also contains a both obscured and unobscured AGNs, and their separate evolution has been determined.

150.06 – The Study of AGN with an Improved Fermi LAT Event Reconstruction

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Contributing teams: The Fermi LAT Collaboration

Blazars dominate the gamma-ray sky above 100 MeV. The second Fermi LAT catalog included 1,298 identified or associated sources, and 84% of them are Active Galactic Nuclei (AGN), mostly blazars. Over the past five years of the Fermi mission, we have measured rapid (20 minute) variability in FSRQs, released several blazar catalogs, used AGN to measure the extragalactic background light and contributed to our understanding of the blazar sequence. Currently there is a major effort underway to completely upgrade the reconstruction and analysis of Fermi LAT data, which will effectively result in an upgraded detector. The resulting data set, called Pass 8, will have a larger acceptance, better PSF at high energies and a wider energy range. These improvements will allow us to better measure the high energy peak of AGN, better constrain AGN variability, and better localize flaring GeV sources. This contribution will detail how these improvements will affect the study of AGN with the LAT.

150.07 – Exploring The Quasar Wind Parameter Space With QWIND

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We present a new version of the QWIND code [Risaliti and Elvis, A&A 516, A89, 2010]. QWIND is a non-hydrodynamical model for the acceleration of line-driven winds arising from the accretion disks of active galactic nuclei (AGNs). Such winds

provide a promising explanation for the origin of gas outflows, which are a common feature of AGNs [Elvis, ApJ, 545, 63, 2000]. Powerful hydrodynamical models [e.g. Proga et al., ApJ, 543, 686, 2000] demonstrate that AGNs can launched disk winds and accelerate them. QWIND 2.0 is a robust, simplified and faster model, focused on the radiative acceleration phase. The model is optimized to examine the existence and properties of the wind for a wide variety of initial conditions including black hole mass, Eddington ratio, and varying gas density and irradiation conditions. QWIND 2.0 uses a new formulation of the basic equations. We demonstrate the numerical stability of the code, illustrate relationships between the parameters, and report initial results applying QWIND 2.0 to surveys of the AGN parameter space.

150.08 – Fermi's Greatest Hits - Insights into the Nature of High Energy Blazar Emission

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Contributing teams: on behalf of the Fermi-LAT Collaboration

Many salient, outstanding questions about the energetics of blazars can only be addressed by quasi-simultaneous, multi-frequency observations. Over the last five years, continuous monitoring of the entire sky by the Fermi LAT in gamma rays has anchored some of the most comprehensive broadband observing campaigns. We review the results of modeling our observations. Despite the considerable variety in the results, a pattern of similarities is emerging that might allow the classification of blazar flares into a few different types.

150.09 – Microlensing Measurements of the X-ray Continuum Emitting Region of the Gravitational Lens SDSS0924+0219

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Microlensing offers a unique way to constrain the physical extent of different emission regions in a lensed quasar, putting to test various accretion and continuum emission models. We perform a joint microlensing analysis using six Chandra observations (spanning six years) of the lensed quasar SDSS 0924+0219 in two energy bands (spanning 0.4-8.0 keV), in which X-ray microlensing variability is detected with high confidence, and high-cadence r-band monitoring (spanning eight years). Our joint microlensing analysis provides robust constraints on the extent of the X-ray continuum emission region and the accretion disk radius, disfavoring models involving an extended X-ray corona.

150.10 – An elusive X-ray iron absorption line in a candidate recoiling supermassive black hole.

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We studied a peculiar X-ray source detected in the Chandra-COSMOS survey at z=0.359. CID-42 is the only source in the survey which clearly shows two optical sources (in the HST/ACS image) embedded in the same galaxy. Civano et al. 2010 and 2012 showed that one source is a bright active galactic nucleus (AGN) recoiling from the center of the galaxy, while the other is most likely a star-forming region in the center of the galaxy. CID-42 was imaged in the X-rays using both XMM-Newton and Chandra satellites. The X-ray spectra show a rare Kalpha line inverted P-Cygni profile, i.e. a redshifted absorption component and an emission component. Redshifted absorption lines are usually explained as high velocity inflows of ionized material

very close to the active black hole. CID-42 absorption feature showed a considerable variability in the line energy peak, implying rapid changes of velocity and ionization state of the infalling material. We present the results of a new XMM-Newton single long (130 ks) observation obtained to perform an accurate modeling of the absorption line. The results show that the highly significant (3 sigma) absorption feature observed between 2003 and 2007 with XMM and Chandra is not present in the new observation. We performed a detailed statistical analysis to understand if this result is due to a physical change in the absorber rather than to an instrumental effect. We also studied the connection between the presence of high velocity inflows and recoiling supermassive black hole.

150.11 – Determining Black Hole Mass of Active Galactic Nuclei Using FWHM of the Hβ Emission Line and Luminosity Relations

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The Narrow Line Emission from an Active Galactic Nuclei contains the Balmer Hβ emission line. These lines are believed to come from material further from the central black hole. The Hβ line can be used to determine the velocity of the gas. The luminosity of the black hole can be determined by applying the extinction correction to the spectral files. The extinction correction accounts for the amount of light that our own galaxy absorbs, giving the true luminosity of the AGN. With both the velocity of the gas and the luminosity, the mass of the black hole can be determined. We have recently began a project using IRAF to measure the FWHM of the Hβ line for a group of AGN selected by the research group of J. Kennefick at the University of Arkansas. This will provide an independent mass determination for use as they seek a correlation with spiral galaxy pitch angle and black hole mass.

150.12 – Check This Out: A Minor Merger in Mrk 509?

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Recently observed by the Hubble Space Telescope as part of a campaign to discover locations and kinematics of AGN outflows, Mrk 509 was found to contain a linear, tidal tail filament in its central regions. Visible in both optical continuum and [OIII] imaging, this feature resembles a 'check mark' of several knots of emission that travel northwest to southeast before jutting towards the nucleus from the southwest. HST STIS observations along the inner portion of the filament reveal redshifted velocities, suggesting that the filament is inflowing. Should this be the case, we may be viewing a minor merger with a dwarf galaxy, and this system would provide a great opportunity to study the fueling of an AGN by a minor merger in progress. We present further observations of the entire filament using Gemini NIFS which clarify the kinematics and characteristics of the filament.

150.13 – WPVS 007: Dramatic Broad Absorption Line Variability in a Narrow-line Seyfert 1

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Blue-shifted broad absorption lines are the manifestation of gaseous outflows in astrophysical phenomena. In active galaxies, these outflowing winds may play a key role in the central engine physics by removing angular momentum and in influencing host galaxy evolution by imparting energy and chemically enriched gas to the surrounding medium. AGN wind variability affords us a valuable tool to study this still poorly understood phenomenon. The existence of a high velocity broad line outflow in WPVS007 is especially extraordinary, as Seyfert-luminosity active galaxies are unexpected to produce them. With its lower luminosity and compact size, the NLS1 galaxy WPVS007 (M_V=-19.7, z=0.02882) provides us the ability to study even colossal variability on merely human timescales. Since its 1996 FOS observation, displaying miniBALs but no true broad absorption lines, WPVS007 has experienced a short but rich history of UV BAL variability. By the 2003 FUSE observation, WPVS007 had developed a BAL with v_max ~ 6000km/s, indicating an optically thick, high velocity outflow. We present the 2010 and 2013 June and December HST COS spectra. Between 2003 and 2010, both the maximum and minimum outflow velocity had increased substantially. As of 2013 June, the continuum emission has since dimmed by a factor of ~2 and the BALs have appeared to weaken, with both decreased maximum and minimum velocities. Such dramatic shifts in BAL velocity are unprecedented, as BAL variability is typically confined to changes in optical depth. What is the nature of the variability in this BAL wind? The upcoming (as of the writing of this abstract) December observation should give us more insight into

tackling that question, whether it be the transient response of a continuous flow to a fluctuating continuum or perhaps the continued decline of a discrete outflow event.

150.14 – Rehabilitating CIV-based Black Hole Mass Estimates in Quasars

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The single-epoch black hole mass scaling relationships that are commonly used to estimate masses for large numbers of quasars currently have significant uncertainties. In particular, the C IV λ1549 relationship is unreliable as a result of emission from low-velocity, non-virialized gas that contaminates the line profile and is associated with the suite of Eigenvector 1 correlations. We have identified a correction for this effect that reduces the scatter between C IV and the more trusted Hβ-based masses by 25%. Furthermore, we explore the effects of Eigenvector 1 biases in samples used to derive C IV scaling relationships, and find that reverberation-mapped samples are significantly biased. As a result, common prescriptions based on such samples have mass biases about 25% too high compared to complete, representative samples.

150.15 – RCT photometry and HCT spectroscopy of blazar candidates in the Kepler field of view.

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The results of photometric and spectroscopic monitoring of 9 blazar candidates in the Kepler field of view are presented. These sources were identified as blazar candidates based on their position in the so-called WISE blazar strip. Finding charts and comparison sequences were created using the NOMAD database. R band photometric monitoring was begun in spring 2013 with the Robotically Controlled Telescope(RCT), and spectroscopic observations of 7 of the sources were obtained with the Himalayan Chandra Telescope (HCT) in September, 2013. Light curves for all 9 sources and preliminary spectroscopic classifications for the 7 sources with spectra will be presented.

150.16 – Multi-wavelength Investigation of Potential Active Galactic Nuclei

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Supermassive black holes (SMBHs) are expected to be found in nearly all massive galaxies exhibiting a nuclear bulge; however, very few are have been observed in low-mass or bulgeless galaxies. Identification of SMBHs in the latter population would provide valuable insights into secular pathways for their growth. To this end, we present a multi-wavelength study of NGC 4670 as an example case for seeking active SMBHs in dwarf galaxies. Like Henize 2-10, this galaxy is an irregular dwarf galaxy with extensive star formation exhibiting x-ray and other signatures suggestive of a potential active black hole.

150.17 – Breaking the Obscuring Screen: A Resolved Molecular Outflow in a Buried QSO

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We present Keck laser guide star adaptive optics observations of the nearby buried QSO F08572+3915:NW. OSIRIS integral field data reveals a compact disk and molecular outflow using Paα and H2 at a spatial resolution of 100 pc. The outflow emerges perpendicular to the disk into a bicone of one-sided opening angle 100° up to 400 pc from the nucleus. The integrated outflow velocities, which reach at least –1300 km/s, correspond exactly to those observed in unresolved OH absorption, but differ from those observed on larger scales in other gas phases. These data represent a factor of >10 improvement in the spatial resolution of molecular outflows from mergers/QSOs, and plausibly represent the early stages of the excavation of the dust screen from a buried QSO.

150.18 – BVRI Photometric Standards in Several AGN Fields

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We present standardized Johnson/Cousins BVRI photometry for comparison stars in the fields of several Active Galactic

Nuclei. Our targets are part of a larger project using reverberation mapping techniques to determine the internal structure of the active region and to estimate the mass of the central black hole. We plan to present standard stars for fields including Zw 229-015, KIC 11178007, Mrk 817, Mrk 50, and NGC 4051. The next step will be to produce well standardized light curves for the active galaxies. All data for this project have been secured using the 0.91-meter telescope at the BYU West Mountain Observatory. We acknowledge support from the Rocky Mountain NASA Space Grant Consortium Fellowship as well as continued support from the Department of Physics and Astronomy at Brigham Young University.

150.19 – Measuring the Clustering Around Normal and Dust-Obscured Quasars at z~2 in the Spitzer Extragalactic Representative Volume Survey (SERVS)

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Contributing teams: Spitzer Extragalactic Representative Volume Survey team

Little is known about the environments of high redshift quasars, particularly those obscured by dust. Previous work suggests that dust-shrouded (type 2) quasars are at least as common as un-obscured optical (type 1) quasars; therefore, in order to fully understand the role quasars play in the evolutionary history of the universe, we must understand both types of objects. This project seeks to explore the environments in which obscured quasars form. In this poster, we present mid-infrared clustering measurements for a sample of 45 quasars with $1.3 < z < 2.5$, a redshift range that is unexplored in the literature. The objects were selected using IRAC multi-color criteria to remove low-redshift starburst and quiescent galaxies, and subsequently had spectroscopy carried out to both obtain redshifts, and to distinguish between type 1 and type 2 quasars; the high-redshift sample presented in this paper is roughly evenly distributed between the two types. We use the SERVS galaxy catalogs to estimate the cross-correlation between each quasar and its surrounding galaxies. The amplitude of this function gives us the richness of the environments in which these quasars are found, and we compare our results with a matched sample with $z < 1.3$.

150.20 – The Far-IR View of an Ultra-Hard X-ray Selected Sample of AGN

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We present early results of the Herschel PACS (70 and 160 µm) and SPIRE (250, 350, and 500 µm) survey of 313 low redshift ($z < 0.05$), ultra-hard X-ray (14-195 keV) selected AGN from the 58 month Swift/BAT catalog. Selection of AGN from ultra-hard X-rays avoids bias from obscuration that are unavoidable at other wavelengths (eg optical, infrared, and radio) providing the most complete sample of AGN to study the connection between nuclear activity and star formation in host galaxies. With the high angular resolution of PACS, we find that ~35% and ~20% of the sources are 'point-like' at 70 and 160 µm respectively with another 20% that have their flux dominated by a point source located at the nucleus. The inferred star formation rates (SFR) of 0.1 - 100 M_{sun} yr^{-1} using the 70 and 160 µm flux densities and the calibration of Calzettti et al (2010) are consistent with those inferred from Spitzer NeII fluxes, but we find that 11.25 µm PAH data give ~3x lower SFR. Using GALFIT to measure the size of the FIR emitting regions, we determined the SFR density [M_{sun} yr^{-1} kpc^{-2}] for our sample, finding a significant fraction to exist above the threshold for star formation driven winds (0.1 M_{sun} yr^{-1} kpc^{-2}, Heckman 2001). Analysis of the SPIRE colors (250/350 and 350/500) also reveals evidence for the presence of nonthermal synchrotron emission from a radio jet significantly affecting the FIR emission at long wavelengths and altering the shape of the spectral energy distribution (SED). We also will present the broad band Herschel 70-500m SEDS for our sample and include archival Spitzer, WISE, FIRST and NVSS data to extend the SED down to near-IR and up to radio wavelengths. The SEDs will be fit using multiple models to attempt to determine the AGN contribution to the FIR (indirect or direct) and ultimately its effect on nuclear star formation.

150.21 – Local Galaxy Density around X-ray AGN and Radio Galaxies in Clusters at Low-z

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We discuss the galaxy environments around previously identified cluster X-ray AGN and radio galaxies in eight low-z clusters ($0.22 < z < 0.34$) to understand the potential triggering mechanism for AGN activity in these dense cluster environments. Using photometric redshift data from the Sloan Digital Sky Survey (DR7 & DR9), we determined the surface density of nearest neighbor galaxies around cluster galaxies and around cluster AGN host galaxies within a 1 Mpc projected radius of the cluster center. We find the galaxy environments around cluster AGN hosts to be consistent with those around typical cluster galaxies, suggesting that the triggering mechanism for non-central cluster AGN may be due to interactions with the intracluster medium.

150.22 – Dust-reddened Quasars in SDSS-III: Trends with Evolution or Orientation?

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We analyze median composite spectra for BOSS QSOs in the redshift range 2.1 to 3.4 sorted by reddening to study trends in the emission and broad absorption line properties. We are particularly interested in reddening as an indicator of the orientation or evolutionary status of the quasar/host galaxy environments. We parameterize the reddening by E(B-V) based on SDSS-WISE W1 colors. The unprecedented large number of high-redshift quasars in BOSS allows us to study important rest-frame UV diagnostics of quasar outflows, accretion rates, and broad emission line physics. Here we present our main results: 1) Redder quasars tend to have stronger and narrower broad emission lines. This is consistent with lower black hole masses and it might support evolution schemes where redder QSOs are younger and closer in time to an initial triggering/infall. 2) The broad absorption lines (BALs) in redder quasars tend to be stronger (deeper). The origin of this trend is not clear but may be related to larger column densities and higher mass loss rates in redder/younger quasars. More work is needed to test relationships to the BAL ionization, accretion rates (L/Ledd), or broad emission line blueshifts. 3) There is the usual Baldwin Effect (smaller emission line REWs with increasing luminosity) when we examine a range in absolute W1 magnitude at fixed E(B-V). We will also discuss comparisons to other quasar samples including extremely red quasars and NLS1s.

150.23 – The luminosity function of AGN selected in the mid-infrared and its implications for cosmic black hole growth

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Our recently completed survey of AGN and quasars selected in the mid-infrared provides a new picture of the AGN luminosity function and its evolution. Mid-infrared selection is less prone to extinction by dust than selection in other wavebands, allowing us to compare the evolution of both the unobscured and obscured population. Using a sample of 479 AGN and quasars that is 90% spectroscopically complete, we find relatively large numbers of obscured AGN at low luminosities and at high redshifts compared to previous estimates from optical and X-ray surveys. We interpret this as the result of the difficulty that AGN have in breaking out of their surrounding cocoon of dust and gas if they have low luminosities, and/or are surrounded by dense material in high redshift host galaxies. We estimate that the luminosity density contributed by AGN is about twice as high as previously thought. Comparison with the local black hole mass density indicates that the average supermassive black hole must be spinning.

150.24 – The WISE View on Water Maser Galaxies

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Extensive searches for water vapor megamasers in active galactic nuclei (AGN) have resulted in ~120 detections out of ~3500 galaxies surveyed. In about 21% of the detections, the masers originate in the sub-pc circumnuclear disks. An investigation of the relationship between the mid-infrared properties and the water maser emission in galaxy centers is essential for both refinement of future maser surveys and for constraining the dominant ionization mechanism most likely associated with the maser activity. We present here the results of a careful cross reference of all galaxies surveyed to date in 22 GHz, offered by the Megamaser Cosmology Project (MCP), with the Wide field Infrared Survey Explorer (WISE) All-Sky Release data, which reveals an impressive overlap of 93% and 98% for maser detections and non-detections, respectively. We find that, while the WISE classification of AGNs based on their redder W1-W2>0.8 colors produces a potential maser detection rate of ~20%, the cut recovers significantly less than half (27%) of all the disk detections to date. We also find that the W3 band (12 microns) appears to offer significant sensitivity to the maser detection for W3<7, as well as for maser disks, with a 13% overall maser detection rate, that includes 62% of all disks detections. We discuss the possibility that the strong connection between the 22 GHz detection and the W3 emission implies a close physical association of the masing conditions with the strength of the PAH feature (11.3 microns) as well as to the warm continuum in AGNs.

150.25 – The AKARI 2.5–5.0μm Spectral Atlas of 83 Local Type-1 Active Galactic Nuclei

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Contributing teams: QSONG team

We present near-infrared (NIR) 2.5–5.0 μm spectra from AKARI observation of 83, nearby (0.002 <z< 0.48), bright (K <14 mag) type-1 active galactic nuclei (AGNs). The sample is selected from bright quasar surveys such as Palomar-Green (PG) survey and SNUQSO survey, and AGNs with reverberation mapped BH masses from Peterson et al. (2004). The 2.5–5.0 μm spectra contain emission lines such as Brα (4.05μm), Brβ (2.63μm), and polycyclic aromatic hydrocarbon (PAH: 3.3μm), that are much less affected by dust than UV or optical lines, thus providing a unique window to understand BH activity and circumnuclear environments. In this paper, we present the spectra for all the 83 AGNs, a composite spectrum of 48 PG QSOs, and measurements of Brackett line FWHMs and line luminosities for 10 AGNs with a reasonable S/N. Furthermore, we derive BH mass estimators using Brα or Brβ, which could be used for studying red AGNs in future. In addition, we find line ratios of the Balmer to the Brackett line to be Brβ/Hβ = 0.076 and Brα/Hβ = 0.093, which are consistent with case B.

150.26 – IFU Observations of Feedback from Radio-Quiet Quasars at z~0.5

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Feedback from black holes is now understood to be a key ingredient in galaxy formation modeling, but direct probes of this process in action are scarce and limited to small samples of active nuclei. Meanwhile, theories have long predicted an evolutionary scenario in which galaxy mergers induce both star formation and nuclear activity, triggering a violent transition from an obscured accretion stage to an unobscured phase as a Type 1 quasar, yet direct evidence is lacking. We present Gemini Integral Field Unit (IFU) observations of the distribution of warm ionized gas (~10^4 K) around two luminous radio-quiet quasars: 11 obscured (Type 2) and 12 unobscured (Type 1) quasars with matched [O III]5007 luminosities (L$_{[O III]}$~$10^{42.7-43.6}$ erg/s) and redshifts (z~0.5). For the Type 2 quasar sample, we have found that their gas nebulae are: (1) existent and extended on galactic scales in every case (15-39 kpc across); (2) nearly perfectly round, in striking contrast with lumpy and/or elongated nebulae around radio galaxies; (3) signifying wide-angle quasi-spherical outflows by their roundness and large velocity dispersion (FWHM?1000 km/s); (4) likely escaping from the host galaxies (the derived median outflow velocity is 760 km/s); (5) showing slightly declining velocity dispersions toward their outer parts (?3% per kpc); (6) blowing winds with high kinetic energy (10^{45} erg/s, ?2% of L$_{bol}$) and mass (2×10^{3-4} M$_{™}$/yr) flows. (7) showing a universal radial profile of [O III]/Hβ; (8) constructing a size-luminosity relation with a flat slope, implying clumpy nebulae that transition from being ionization-bounded at small radii to being matter-bounded in the outer parts. For the Type 1 quasar sample, we also detect extended nebulae surrounding all quasars with sizes, morphology and gas kinematics surprisingly similar to the Type 2 quasar nebulae. In conclusion, **energetic quasi-spherical outflows are ubiquitous in luminous quasars of all types at z~0.5**. Such striking smooth and round large-scale gas nebulosities are inconsistent with illuminated merger debris and may be the signature of accretion energy reaching gas at large scales. These findings are likely the long-sought direct evidence for galaxy-scale quasar feedback.

150.27 – A multi-parameter statistical analysis of the connection between water maser emission and nuclear galactic activity

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Water mega-maser disks currently provide the most accurate and direct method for calculating distances to galaxies and for weighing supermassive black holes (SMBHs). Moreover, high spatial resolution radio mapping of these systems provides a direct view of the AGN accretion disk on sub-pc scales. It is thus of great importance to understand how the maser emission and the masing conditions relate to their host galaxies' properties, and in particular, with their nuclear nebular activity. We present here the results of a comprehensive multi-parameter analysis of high-quality photometric and spectroscopic measurements of galaxies surveyed for water maser emission. We use both individual parameter correlation analyses and a Principal Component Analysis to constrain the type and range of optical characteristics that best associate with various morphologies and strengths of water maser activity. We discuss these results in the frame of current proposed models of galactic evolution, and suggest that the mega-maser phenomenon could be related to a certain brief phase in the active galactic nucleus lifetime. This analysis provides new sophisticated yet feasible criteria for targeting these systems in new surveys with a projected four-fold increase in the detection rate.

150.28 – Discovery of Misaligned Radio Emission in Galaxy Cluster Zw CL 2971

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In a search for green valley galaxies with radio loud active galactic nuclei (AGN), we found one such object that may be associated with the cluster of galaxies Zw CL 2971 (z = 0.098). Serendipitously, we found in this cluster a strong bent-jet radio source associated with the cluster's central dominant (cD) elliptical galaxy. The center of the cD galaxy is coincident (0.35 arcsecond) with the second brightest spot of radio continuum emission (34.3 mJy as measured by FIRST), but the brightest radio hotspot (66.8 mJy) is offset by 4.6 arcseconds (~9 kpc at the redshift of the cluster) and has no visible counterpart. Furthermore, the optical spectrum of the cD galaxy has only weak emission lines, suggesting the absence of a currently active nucleus. It is possible that the counterpart is optically faint (possibly due to a recently completed duty cycle) or is not visible due to movement or position. If the radio source is a distant background object, then the brighter jet is most likely magnified by gravitational lensing. If the radio source is located at the redshift of the cluster, then the brighter radio jet trails backward toward and past the cD galaxy to a distance of ~120 kpc, while the fainter jet is bent at a nearly orthogonal angle, ~40 kpc away from the brightest radio hotspot, in the opposite direction. These geometric offsets could be used to constrain the duty cycle history of the AGN creating the radio emission, as well as the dynamical properties of the intracluster medium.

150.29 – Diffuse radio emission around FR II sources as exemplified by 3C452

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We have discovered a pair of megaparsec size radio lobes of extremely steep spectrum straddling the well-known classical double radio source 3C452. For the past several decades 3C452 has been regarded as a textbook example of an edge-brightened double radio source of Fanaroff-Riley type II (FR II) but we show it to be a bonafide "double-double" radio galaxy (DDRG). The inner double fed by the jets has evolved into a perfectly normal FR II radio source. Thus, 3C452 presents a uniquely robust example of recurrent nuclear activity in which the restarted jets are expanding non-relativistically within the relic synchrotron plasma from an earlier active phase. This situation contrasts markedly with the strikingly narrow inner doubles observed in a few other DDRGs that have been interpreted in terms of compression of the synchrotron plasma of the relic outer lobes at the relativistic bow-shocks driven by the near ballistic propagation of the two inner jets through the relic plasma. We also present additional examples of the occurrence of faded outer lobes around well defined FRII sources, using our deep GMRT images at meter wavelengths processed with AIPS++ software. We also examine the statistics of the occurrence of such sources using a flux density limited sample. A key ramification of our findings are that they caution against the use of FR II classical double radio sources for testing cosmological models and unification schemes for active galactic nuclei.

150.30 – Decomposition of Host Galaxies of Nearby Type 1 Active Galactic Nuclei

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We present detailed image analysis of 235 nearby type 1 active galactic nuclei obtained from the HST archive using GALFIT 3.0. We examine how the physical parameters of the host galaxies correlate with those of AGNs. We find that broad-line type 1 and radio-loud AGNs preferentially live in early-type galaxies. Narrow-line type 1 AGNs show a high bar fraction and a low fraction of tidal interaction, suggesting that interaction time scales and frequencies may differentiate between broad-line and narrow-line type 1 AGNs. Finally, we present the bulge scaling relation between AGN host galaxies and normal galaxies. The AGN sample follows a similar size-luminosity relation as for normal galaxies but with a slightly different zero-point, such that the bulges of AGNs tend to be more luminous than the bulges of inactive galaxies. Indeed, at a fixed size, bulges with a more rapidly accreting nucleus appear to be brighter in surface brightness compared to bulges with a smaller Eddington ratio, perhaps due to younger stellar populations.

150.31 – The Low-Luminosity End of the Radius-Luminosity Relationship for Active Galactic Nuclei

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We present an updated and revised analysis of the relationship between the Hβ broad-line region (BLR) radius and the

luminosity of the active galactic nucleus (AGN). Specifically, we have carried out two-dimensional surface brightness decompositions of the host galaxies of nine new AGNs imaged with the Hubble Space Telescope Wide Field Camera 3. The surface brightness decompositions allow us to create "AGN-free" images of the galaxies, from which we measure the starlight contribution to the optical luminosity measured through the ground-based spectroscopic aperture. We also incorporate 20 new reverberation-mapping measurements of the Hβ time lag, which is assumed to yield the average Hβ BLR radius. The final sample includes 41 AGNs covering four orders of magnitude in luminosity. The additions and updates incorporated here primarily affect the low-luminosity end of the R-L relationship. The best fit to the relationship using a Bayesian analysis finds a slope of $\alpha = 0.533^{+0.035}_{-0.033}$, consistent with previous work and with simple photoionization arguments. Only two AGNs appear to be outliers from the relationship, but both of them have monitoring light curves that raise doubt regarding the accuracy of their reported time lags. The scatter around the relationship is found to be 0.19 ± 0.02 dex, but would be decreased to 0.13 dex by the removal of these two suspect measurements. A large fraction of the remaining scatter in the relationship is likely due to the inaccurate distances to the AGN host galaxies. Our results help support the possibility that the R-L relationship could potentially be used to turn the BLRs of AGNs into standardizable candles. This would allow the cosmological expansion of the universe to be probed by a separate population of objects, and over a larger range of redshifts.

150.32 – HI Spectroscopy of Reverberation-Mapped Active Galactic Nuclei Host Galaxies

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We present the initial results of distances and neutral hydrogen (HI) mass measurements for 27 host galaxies of black holes in a sample where black hole mass measurements have been determined from reverberation mapping. Our data sets draw from our HI spectroscopy from the Green Bank Telescope, and ground-based optical and infrared images. We utilize the line-width - luminosity Tully-Fisher relation to provide a galaxy luminosity from the measured HI line width, and we determine the host galaxy apparent magnitude by modeling the galaxy brightness profile in the optical images. The brightness profile modeling separates the central active nuclei point source contribution so that the host galaxy brightness profile can be measured more accurately. Comparison of the luminosity with the apparent galaxy magnitude yields a constraint on the distance to the galaxy. Previous galaxy distances in this sample have been estimated using redshift. Our Tully-Fisher distance measurements will help reduce scatter in black hole scaling relationships, including the correlation between the radius of the broad emission line region and the luminosity of the central active galactic nucleus. Minimizing the uncertainty in this relation is crucial, as many inferences regarding active black holes cosmic distances rely upon these black hole scaling relations. Additionally, we obtain the HI gas mass from the total integrated HI of the spectrum. Future work will progress toward constraining the dark matter mass to explore possible relations between the total galaxy mass with black hole mass and dark matter mass with black hole mass.

150.33 – The Black Hole Mass-Bulge Luminosity Relationship for Reverberation-Mapped AGNs in the Near-IR

Emily Nicholas[1], Misty C. Bentz[1]
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We present preliminary results for a near-IR M-L scaling relationship for active galaxies in the reverberation sample. We are particularly interested in the effect of host-galaxy morphology on the M-L scaling relationship. In order to study evolution over cosmic time we must employ scaling relations, which are calibrated to the direct methods of black hole mass measurement and rely on correlations between host galaxy properties and black hole masses. However, it remains uncertain which scaling relation most reliably predicts black hole masses based on host galaxy observables. Recent studies of the M-relationship have uncovered a possible offset in the relationship due to the presence of a pseudobulge or bar in the host galaxy. This offset would adversely affect one's ability to use the M-relationship as a way to estimate black hole masses efficiently because it would require the detailed morphology of the galaxy to be known a priori. Preliminary results based on optical HST data suggest that the M-L relation for active galaxies with reverberation-based black hole masses is not plagued by the same offsets. However, due to dust and on-going star formation, the optical data yield an M-L relationship with a slightly higher scatter than the M- relation. We have carried out near-IR imaging with the WIYN High-Resolution Infrared Camera (WHIRC) on the WIYN telescope to minimize the effects of dust and star formation in order to test whether the M-L relationship is a more accurate predictor of black hole masses and a potentially more fundamental relationship. The imaging campaign has been completed, and we are currently in the process of carefully modeling the galaxy surface brightness features so that we can accurately remove the contribution from the point spread function of the active nucleus. We present our preliminary results here, and we expect that the final results will prove to be quite useful in conjunction with future large imaging surveys, such as LSST, which have no dedicated spectroscopic component. Our team is also in the process of improving distance measurements to these galaxies, which could potentially help to decrease the scatter in bulge luminosity measurements for the reverberation sample.

150.34 – Alignments of Radio Sources in the GMRT ELAIS N1 Deep Field

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Results of the active galactic jet position angle alignments in the ELAIS N1 Deep radio survey are presented here. The ELAIS N1 deep radio survey was carried out with the Giant Meter-wave Radio Telescope at 615 MHz. The deep field is a seven pointing mosaic that covers 1.0 square degrees of the ELAIS N1 field with an average angular resolution of 5 arcsec by 5 arcsec, across the mosaic. The average sensitivity of the mosaicked image is 10 microJy/beam in Stokes I. There were 65 extended radio galaxy jets extracted from the mosaic of which 33 galaxies have redshift information available. The position angles of radio galaxy jets are expected to be uniform, but the radio galaxy jets in our sample were found to deviate from uniform distribution of positions angles to 99 percent significance level. Further testing with angular covariance reveals alignments in radio position angles, across angular scales of up to 1.8 degrees. Position angle correlations at scales of 1.8 degrees translates to a co-moving scale of 53 Mpc at a redshift of 1. These results corroborate prior evidence for large scale alignments in quasar optical polarization studies. The absence of interfering propagation effects that introduce uncertainty in optical polarization studies makes the study of radio galaxy jet position angles an attractive alternative methodology.

150.35 – Mean and Extreme Radio Properties of Quasars and the Origin of Radio Emission

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We explore the evolution of the fraction of radio loud quasars and the mean radio properties of quasars. Although any quasar has only a ~10% chance of being radio loud and the average quasar has a radio luminosity of ~4x10^30 ergs/s/Hz, these properties are strong functions of not only luminosity, redshift, black hole mass, and accretion rate, but also the strength of the accretion disk wind (as characterized by CIV emission line properties). Quasars with higher optical luminosity and/or lower redshift have a higher than average probability of being radio loud, but their median radio luminosity (relative to optical) is much lower than average. We find that, while radio properties of quasars generally cannot be predicted from their optical properties, objects where one expects a strong radiation line driven wind (based on emission line features) have virtually no chance of being radio loud. The redder quasars are in the optical, the more radio flux (relative to optical) they have; this trend holds even for quasars that are not expected to be significantly dust reddened/extincted in the optical. Finally, we consider the radio properties of quasars in the framework of models which describe the radio loud extrema as being due to particularly high spin resulting from second generation mergers and in the context of star formation at lower levels of radio flux. This work was supported by NSF AAG grant 1108798.

150.36 – The Complex North Transition Region of Centaurus A

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Contributing teams: GALEX Science Team

We present deep radio images of the inner 50 kpc of Centaurus A, taken with the VLA at 327 MHz, with an emphasis on the transition regions between the inner galaxy -- including the AGN, inner radio lobes and star-forming disk -- and the outer radio lobes. Our images of the North Middle Lobe show that the so-called ``outer jet'' reported by Morganti et al. (1999) does not appear to be a collimated flow from the AGN, but rather is part of a narrow ridge of emission within a broader, diffuse, radio-loud region. This knotty radio ridge is coincident with other striking phenomena: active star formation, emission-line gas filaments, disrupted HI streams and compact X-ray knots. We also present deep GALEX images of the parent galaxy,NGC 5128. We detect strong Far-UV emission associated with the galaxy's central dust lane and show the disk is undergoing a starburst of at least 8 solar masses per year. A ``ribbon'' of Far-UV emission extends to a distance of at least 35 kpc from the galaxy center, apparently associated with the radio ridge and H_α filaments. Since the outer lobes of Cen A are currently ``alive'', both must be powered by energy flowing through the transition regions. In the absence of a narrow jet flow through the transition regions, the requisite energy must be transported by a broad outflow, such as a galactic wind. We show that such a wind is plausible, and speculate that the diverse ``weather'' now seen in the Northern Transition Region is caused by a hot wind encountering cool gas left behind by one of the recent merger/ encounter events which have characterized the history of NGC 5128.

150.37 – The Periodicity of the Tev Blazar Mrk 501

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Contributing teams: BYU's Remote Observatory for Variable Object Research (ROVOR)

We have monitored the TeV blazar Markarian 501 from 2009 to 2013 in Johnson R using the Brigham Young University 16"
ROVOR telescope. Mrk 501 was remarkably stable during this time allowing the opportunity to examine its behavior during
long quiescent periods. We discovered a small sinusoidal variation in its magnitude having an amplitude of 0.03 magnitudes
and a period of 130 days which is essentially twice the period of the x-ray variation discovered by Abdo et al. We present our
data and discuss possible interpretations. Topics- galactic--AGN, Blazars: individual (Mrk 501)

150.38 – A spectroscopic survey of WISE-selected obscured quasars with SALT

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States.*

We present the results of an optical spectroscopic survey of a sample of obscured quasars selected identified on the basis of
their mid-infrared emission detected by the Wide-Field Infrared Survey Explorer (WISE). The survey utlilizes the Robert
Stobie Spectrograph (RSS) on the Southern African Large Telescope (SALT). Our target objects are selected to have red
WISE colors characteristic of AGN, as well as red optical to mid-IR colors indicating that the optical/UV AGN continuum is
obscured by dust. We obtain secure redshifts for the majority of our sample, and find that sources that are bright in the WISE
22 micron band are typically at moderate redshift (z~0.2-0.5) while 22 micron fainter sources are at higher redshifts. The
majority of the sources have narrow emission lines, with optical colors and emission line ratios of our WISE-selected sources
that are consistent with the locus of AGN on the color-excitation diagram. These results verify the efficiency of WISE color
criteria in selecting luminous obscured AGN. This material is based upon work supported by the National Science Foundation
under Grant Nos. 1211096 and 1211112, and by the NASA ADAP under Grant No. NNX12AE38G.

151 – Stellar Atmospheres, Winds Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

151.01 – Are the Winds of Young Sun-like Stars Strong or Weak?

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We study the stellar wind of the young, Sun-like star Pi1 UMa (G1.5 V, t~0.3 Gyr), using spectroscopic observations from the STIS instrument on the Hubble Space Telescope (HST). Currently the only way to detect the coronal winds of Sun-like stars is through H I Lyman-alpha absorption from astrospheres (i.e., the interaction regions between stellar winds and the ISM). Past work on this absorption has demonstrated that younger, more coronally active stars tend to have stronger winds than older stars like the Sun, with winds being up to 100 times stronger than the solar wind for stars with ages of t~0.7 Gyr. However, observations of two stars that are even younger and more active than this, EV Lac (M3.5 V) and Xi Boo A (G8 V), have implied surprisingly weak winds, suggesting that stellar winds are actually somehow inhibited in the coronae of the youngest and most active stars. From new HST/STIS observations of Pi1 UMa, we report a detection of astrospheric Lyman-alpha absorption for Pi1 UMa, and we find that the amount of absorption implies a mass loss rate of only 0.5 times that of the Sun. This provides support for the notion that very young and active stars actually have surprisingly weak winds. However, we also speculate about alternative interpretations of the Lyman-alpha data involving the assumption of an unconventional surrounding ISM, which could allow the Pi1 UMa data to be consistent with a much more massive wind.

151.02 – Reinvestigating the Lambda Boo Stars

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The peculiar nature of Lambda Bootis was first introduced in 1943. Subsequently, Lambda Boo stars have been slowly recognized as a group of A-type Population I dwarfs that show mild to extreme deficiencies of iron-peak elements, although C, N, O, and S can be near solar. MK classification criteria include broad hydrogen lines, a weak metallic-line spectrum compared to MK standards, coupled with a particularly weak Mg II 4481 line. This intriguing stellar class has recently regained the spotlight because of the directly imaged planets around a confirmed Lambda Boo star-HR 8799 and a probable Lambda Boo star-Beta Pictoris. The possible link between Lambda Boo stars and planet-bearing stars motivates us to study Lambda Boo stars systematically. However, Lambda Boo candidates published in the literature have been selected using widely different criteria. The Lambda Boo class has become somewhat of a "grab bag" for any peculiar A-type stars that didn't fit elsewhere. In order to determine the origin of Lambda Boo stars' low abundances and to better discriminate between theories explaining the Lambda Boo phenomenon, a refined working definition of Lambda Boo stars is needed. We have re-evaluated all published Lambda Boo candidates and their existing spectra. After applying a consistent set of optical/UV classification criteria, we identified over 60 confirmed and over 20 probable Lambda Boo stars among all stars that have been suggested as Lambda Boo candidates. We are obtaining new observations for those probable Lambda Boo stars. We also have explored the possible link between debris disks and Lambda Boo Stars.

151.03 – Analyzing Starspots with TiO bands: Comparing Fits Using Synthetic Spectra to Proxy Stars

Douglas B. O'Neal[1], Joel R. Skivington[1]
1. Keystone College, La Plume, PA, United States.

In several studies, we have measured starspot filling factors and temperatures on magnetically active stars using TiO bands. In the past we have used proxy star spectra to model the spots and the inactive photosphere of the active stars. Now, we extend this work by using model atmospheres and synthetic spectra, based on the Atlas9 models, to fit the spectra of active stars. We have studied our past spectra of several giant/subgiant RS CVn and dwarf BY Dra active stars, including an extensive data set on II Pegasi. We find systematic differences between the starspot parameters obtained using proxy stars and synthetic spectra. When only the 7055 A TiO band is used and a spot temperature is assumed, we compute ~0.1 lower spot filling factor when synthetic spectra are used compared to proxy stars. When the 7055 A and 8860 A TiO bands are used simultaneously, we systematically find a slightly higher spot filling factor and a spot temperature ~200 K lower using synthetic spectra. We are currently working to explain these differences.

151.04 – Mapping the interacting winds of Eta Carinae: Changes Across the

Apastron

Theodore R. Gull[1], Thomas Madura[2, 1], Michael F. Corcoran[3, 1], Kenji Hamaguchi[4, 1], Mairan Teodoro[5, 1]

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Since the May 2009 servicing mission to repair the Hubble Space Telescope, we have systematically mapped the central 1-2" region of Eta Carinae with the 0.1"-wide, long slit of the Space Telescope Imaging Spectrograph. Six mappings of selected forbidden emission lines began in the late recovery after the 2009.1 periastron event and now extend to phase 0.85 of Eta Carina's 5.54 year period. In addition to the recovery of the high state as depicted by [Fe III] (IP=16.6 eV) strictures and the stabilization of [Fe II] (IP=7.8 eV) features, we see components of at least three wind-blown shells that expand outward at 400 to 500 km/s. Virtually all forbidden emission originates from primary wind structures. The [Fe II] shells, moving at 470 km/s, are primary wind (420 km/s) structures slightly accelerated by the fast secondary wind (Teodoro et al, 2013 ApJ 773, L16T). The [Fe III] arcs, directly photo-ionized by the secondary star, also shift outward with time. Structures in both emissions shift in a general clockwork direction consistent with the derived orbital motion by Gull et al (2009 MNRAS 396, 1308) and revised by Madura et al (2012 MNRAS 420, 2064). With the continued development of the 3D hydrodynamic models we are able to compare the changing structures and determine limits to changes in the mass loss rate over this period of time. Additional mappings, to be obtained by seven additional HST visits, are scheduled at selected orbital phases to follow major changes in ionization structue due to the drop of high ionization to low ionization across the 2014.5 periastron passage. This work is funded by NASA grants to support HST research.

151.05 – Mining the HST "Advanced Spectral Library (ASTRAL) - Hot Stars": The High Definition UV Spectrum of the Ap Star HR 465

Kenneth G. Carpenter[1], Thomas R. Ayres[2], Krister E. Nielsen[3], Gladys V. Kober[3], Glenn M. Wahlgren[3], Saul J. Adelman[4], Charles R. Cowley[5]

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The "Advanced Spectral Library (ASTRAL) Project: Hot Stars" is a Hubble Space Telescope (HST) Cycle 21 Treasury Program (GO-13346: Ayres PI). It is designed to collect a definitive set of representative, high-resolution (R~30,000-100,000), high signal/noise (S/N>100), and full UV coverage (~1200 - 3000 A) spectra of 21 early-type stars, utilizing the high-performance Space Telescope Imaging Spectrograph (STIS). The targets span the range of spectral types between early-O and early-A, including both main sequence and evolved stars, fast and slow rotators, as well as chemically peculiar (CP) and magnetic objects. These extremely high-quality STIS UV echelle spectra will be available from the HST archive and, in post-processed and merged form, at http://casa.colorado.edu/~ayres/ASTRAL/. The UV "atlases" produced by this program will enable investigations of a broad range of problems -- stellar, interstellar, and beyond -- for many years to come. We offer a first look at one of the earliest datasets to come out of this observing program, a "high definition" UV spectrum of the Ap star HR 465, which was chosen as a prototypical example of an A-type magnetic CP star. HR 465 has a global magnetic field of ~2200 Gauss. Earlier analyses of IUE spectra show strong iron-peak element lines, along with heavy elements such as Ga and Pt, while being deficient in the abundance of some ions of low atomic number, such as carbon. We demonstrate the high quality of the ASTRAL data and present the identification of spectral lines for a number of elements. By comparison of the observed spectra with calculated spectra, we also provide estimates of element abundances, emphasizing heavy elements, and place these measurements in the context of earlier results for this and other Ap stars.

151.06 – High-Dispersion IR Spectroscopy of Mira Variables with the Spitzer IRS

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We report on the first set of IR spectra taken of Mira-type variable stars under high dispersion with the Infrared Spectrograph (IRS) onboard the Spitzer Space Telescope. A sample of 25 galactic Miras was observed in the 10-37 micron spectral regime anywhere from two to several times during their pulsation cycle. Many of the stars observed show marked changes in overall flux levels as a function of phase. We are able to identify many strong emission lines and emission features due to silicate and carbon dusts and molecular constituents. In addition, strong emission lines from neutral and singly ionized metals were also seen. Finally, a strong absorption feature was seen near 13.7 microns in the carbon star U Lyr at six different phases spanning 0.572 to 0.909 of the pulsational phase. This absorption feature is likely due primarily to the Q, v5 band at 13.70978 microns of the C2H2 molecule, with perhaps some contamination of the n5 band of CHCH at 13.716 microns. This work was financially supported through a NASA Spitzer grant for Program GO 50717.

151.07 – Time-Resolved X-ray Spectroscopy of the Massive Binary delta Ori

Joy S. Nichols[1], Y. Naze[2], Michael F. Corcoran[3], A. Pollock[4], Anthony F. Moffat[7], R. Ignace[5], Wayne L. Waldron[6], Nancy R. Evans[1]
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We have obtained 500 ks of Chandra HETG observations of the massive binary delta Ori (O9.5II+unseen companion), one of the fundamental calibrators of the mass-luminosity-radius relation in the upper HR diagram. The program is intended to map the emission line parameters as the secondary moves through the wind of the primary star. Custom extraction techniques have been developed to create 12 time-resolved 40 ks spectra from these observations, each of which is properly calibrated for time and temperature effects. Emission line fluxes for these time slice spectra are presented, as well as phase analysis of the variability of the fluxes. We discuss the interpretation of the resulting data, such as colliding winds and occultation of various temperature regimes of the primary wind by the secondary.

151.08 – Strong-Flare Rates of Solar-Like Stars in Kepler Cluster NGC 6811

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Strong flares on the Sun are accompanied by intense ionizing radiation (X-rays, far UV) and are often associated with coronal mass ejections (CMEs), which can be hazardous to astronauts, and infrastructure such as satellites and electrical systems. The rates of the largest flare events are, however, poorly known. By taking advantage of the exquisite precision of Kepler photometry, we derive white light flare distributions for a sample of near-solar-mass (G1-G5) dwarfs in NGC 6811 (age ~ 1 Gyr). Using a solar-based relationship, we estimate the X-ray emission from these flares in order to compare the results to other solar and stellar X-ray flare data. We also take a first look at some stars of different masses, to study the mass dependence of flaring at fixed age, and explore the implications of our results for the rates of the largest flaring events on the Sun. This work was supported by Kepler grants NNX11AC82G and NNX13AC29G and NASA HGI grant NNX10AF29G.

151.09 – Eta Carinae's change of state: First new HST/NUV data since 2010, and the first new FUV since 2004

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During the past 15 years Eta Carinae has exhibited a critical phase in its recovery from the 19th century "Great Eruption." Dramatic changes in the ultraviolet brightness and spectrum between 1998 and 2010 indicated a surprisingly rapid increase in the UV flux of the central star and then a corresponding decrease in its mass-loss rate. We report the first UV photometry and spectra of Eta Carinae since 2010 and the first far-UV spectra in almost 10 years, obtained with the Hubble Space Telescope in September and November 2013. These measure the long-term secular changes prior to the onset of the anticipated spectroscopic event in August 2014.

151.10 – Measurements of the Stellar Wind Strengths of Planet-Hosting G- and K-Type Stars

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Voyager 1 has recently crossed the heliosphere, where the solar wind meets the material of the interstellar medium. With line of sight spectral information provided by the STIS on Hubble, the analogous boundary around other stars, which is known as an astrosphere, can be detected. We are conducting a thorough analysis of MgII, FeII, DI, and HI Lyman-alpha absorption along the lines of sight to a sample of nearby K and G stars in order to obtain and use astrospheric detections to estimate stellar wind strengths, and to study their effects upon exoplanetary atmospheres. Each astrospheric measurement is obtained by careful examination and reconstruction of the Lyman-alpha emission feature, which ultimately provides an estimate of the neutral hydrogen column density associated with a star's astrosphere. The amount of neutral hydrogen in that region is

highly dependent on the stellar wind strength of the host star, and is one of the scant few methods available today for measuring that quantity. If stellar winds are strong enough, they can be responsible for stripping a nearby planet of its atmosphere, as was potentially the case with Mars and our Sun approximately 4 billion years ago. Increasing the sample size of measurements of stellar wind strengths for K and G type stars will allow for us to more accurately determine the influence of solar-type host stars on their respective exoplanetary systems. Included in our sample are the stars HD9826 and HD192310, which both have confirmed exoplanets in orbit. This project includes the reconstructions of the Lyman-alpha emission feature along the lines of sight to a sample of nearby stars, with a determination of whether or not astrospheric or heliospheric absorption is detected in each instance, with hydrogen column densities for positive detections. We would like to acknowledge NASA HST Grant GO-12475 awarded by the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., for NASA, under contract NAS 5-26555, and a student fellowship from the Connecticut Space Grant Consortium for their support of this research, as well as the Astronomy faculty and students at Wesleyan University.

151.11 – X-ray Emission from Eta Carinae near Periastron in 2009: Origin of the X-ray Minimum

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X-ray emission from the supermassive binary system, Eta Carinae, declines sharply around periastron. This X-ray minimum has two distinct phases --- the lowest flux phase in the first ~3 weeks and a slightly brighter phase thereafter. In 2009, the Chandra X-ray Observatory monitored the first phase five times and found the lowest observed flux at ~1.9e-12 ergs cm-2 s-1 (3-8 keV). The spectral shape changed such that the hard band above ~4 keV dropped quickly at the beginning and the soft band flux gradually decreased to its lowest observed value in ~2 weeks. The hard band spectrum had begun to recover by that time. This spectral variation suggests that the shocked gas producing the hottest X-ray gas near the apex of the wind-wind collision (WWC) is blocked behind the dense inner wind of the primary star, which later occults slightly cooler gas downstream. Shocked gas previously produced by the system at earlier orbital phases is suggested to produce the faint residual X-ray emission seen when the emission near the apex is completely blocked by the primary wind. The brighter phase is probably caused by the re-appearance of the WWC plasma, whose emissivity significantly declined during the occultation. We interpret this to mean that the X-ray minimum is produced by a hybrid mechanism of an occultation and a decline in emissivity of the WWC shock. We constrain timings of superior conjunction and periastron based on these results.

151.12 – Metallicity Analysis of Planetary Hosts Kepler 37, 62, & 68

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This study aims to examine the effect of stellar metallicity on planet formation in multi-exoplanet systems discovered by NASA's Kepler spacecraft. We have analyzed Keck/HIRES spectra of the planetary hosts Kepler 37, 62, and 68 systems and derived the abundances of 15 elements for these stars. Results from previous studies have suggested that stellar abundance patterns or "signatures" may indicate the presence of planets, possibly terrestrial planets in particular, and thus such patterns may be used to identify stars with planets, including potentially Earth-size terrestrial planets. Here we present the results of our abundance analysis of three stars with Earth-size planets discovered by Kepler.

151.13 – Interplanetary proton flux and solar wind conditions for different solar activities interacting with spacecraft and astronauts in space

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The goal of this research is to determine the interplanetary proton flux and solar wind conditions by using data from several satellites such as Advanced Composition Explorer (ACE), Geostationary Operational Environmental Satellites (GOES) in particular GOES 9, GOES 11, GOES 12, GOES 13, and Solar Heliospheric Observatory (SOHO) to determine proton flux in different solar wind conditions. The data from above satellites were used to determine space weather conditions in which the goals are to evaluate proton fluxes for four periods of solar cycle activity: a solar cycle 23/24 minimum (2008), close to a solar cycle 22/23 minimum (1997), with intermediate activity (2011) and for about maximum activity for the cycle 23 (2003), to compare data of two period of solar cycle in 2003 and 2008 (Max vs. Min), to compare data of two period of solar cycle in 1997 and 2008 (Min vs. Min), to compare soft X-ray flux from SOHO with proton 1-10 MeV flux from GOES 9 for strong flare in 1997. To conclude the above evaluations are being used to determine the interaction between the space weather conditions and the following consequences of these conditions important for astronautics and everyday human activity: 1-

Satellite and Spacecraft charging, 2-Dangerous conditions for onboard electronics and astronauts during strong solar flare events, and 3- Total Electron Content (TEC), Global Positioning System (GPS), and radio communication problems related to solar activity.

151.14 – The Delta Ori Very Large Project: X-ray Emission and Stellar Variability

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Delta~Ori is the nearest massive, single-lined eclipsing binary (O9.5~II+OB, $P=5^{d}.7324$). High resolution X-ray spectrometry combined with high-precision photometry from space offers a unique opportunity to geometrically measure the dynamics of the shocked gas around the primary star. We summarize our recent campaign of phase-constrained high-resolution X-ray spectra obtained with the CHANDRA/HETGS plus high-precision optical photometry with MOST. These observations provide local measurement of the distribution of the embedded, X-ray emitting shocks in the wind of an O star via radial velocity variations and occultation effects, along with standard f/i ratio diagnostics, and enable us to look for correlations with the broad-band photometric variability. We discuss how these observations can help determine the primary star's clumping-corrected mass loss rate, and resolve critical uncertainties in our understanding of the connection between stellar and mass loss parameters.

151.15 – Modeling the Dusty Envelope Around AGB Stars

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Stellar Population Synthesis (SPS) models are used to infer a host of galactic properties including star formation histories, rates, and stellar masses. However, most SPS models neglect the effect of circumstellar dust shells around evolved stars. To overcome this shortcoming we have created a new grid of circumstellar dust models for AGB stars. We couple the dust models to a new generation of isochrones that include TP-AGB stars (Choi et al. in prep). We show that circumstellar dust from AGB stars can make a significant contribution to the mid-IR of star-forming galaxies. Furthermore, we test the circumstellar dust models by fitting observed data for AGB stars and find that the models are in good agreement with the data. This grid was created to be included in the FSPS model described in Conroy and Gunn 2010. We describe the preliminary results from including the improved TP-AGB models in FSPS.

151.16 – The "Horns" of FK Comae and the Complex Structure of its Outer Atmosphere

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As part of a large multiwavelength campaign (COCOA-PUFS*) to explore magnetic activity in the unusual, single, rapidly rotating giant FK Comae, we have taken a time series of moderate resolution FUV spectra of the star with the COS spectrograph on HST. We find that the star has unusual, time-variable emission profiles in the chromosphere and transition region which show horn-like features. We use simple spatially inhomogeneous models to explain the variable line shapes. Modeling the lower chromospheric Cl I 1351 Å line, we find evidence for a very extended, spatial inhomogeneous outer atmosphere, likely composed of many huge "sling-shot" prominences of cooler material with embedded in a rotationally distended corona. We compare these results with hotter hotter transition region lines (Si IV) and optical spectra of the chromospheric He I D3 line. We also employ the model Cl I profiles, and data-derived empirical models, to fit the complex spectral region around the coronal Fe XXI 1354.1 Å line. We place limits on the flux of this line, and show these limits are consistent with expectations from the observed X-ray spectrum. *Campaign for Observation of the Corona and Outer

Atmosphere of the Fast-rotating Star, FK Comae

151.17 – The Atmospheric Response to High Fluxes of Nonthermal Electrons during M Dwarf Flares

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Flares are thought to be the result of magnetic fields in the stellar corona that undergo reconnection and accelerate charged particles into the lower atmosphere. Spectra of M dwarf flares in the optical and near-ultraviolet wavelength regimes can be used to constrain the heating mechanism of the lower stellar atmosphere. These observations show several ubiquitous properties of the continuum emission, which is not reproduced by models that use typical "solar-type" heating functions. We present results from a grid of new flare models using the RADYN code, which simultaneously calculates the radiative transfer and hydrodynamics on short timescales. We explore the atmospheric response to a short ~2 second burst of a very high heating rate from nonthermal electrons using a solar-type heating function, and we propose a new "M dwarf-type" heating variation that explains a range of observed spectral properties, such as ~10,000 K blackbody emission and a smooth continuum across the Balmer jump wavelength (3646A).

151.18 – Detection of Thermal Radio Emission from Evolved Solar-Type Stars with the Jansky VLA

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We present the first detections of thermal radio emission from the atmospheres of evolved solar-type stars ? Cet, ? Cas A, and 40 Eri A. These stars all resemble the Sun in age and level of magnetic activity, as indicated by X-ray luminosity and chromospheric emission in calcium H and K lines. We observed these stars with the Jansky VLA with sensitivities of a few μJy at combinations of 10.0, 15.0, and 34.5 GHz. All three stars are detected at 34.5 GHz with signal-to-noise ratio of between 4.3 and 8.4, with upper limits at 10.0 and/or 15.0 GHz that imply a rising spectral index. The measured 34.5-GHz fluxes correspond to stellar disk-averaged brightness temperatures of roughly 10,000 K, similar to the solar brightness temperature at the same frequency. We explain this emission as optically-thick thermal free-free emission from the chromosphere, with the possibility of a minor contribution from coronal gyroresonance emission above active regions.

152 – Stellar Evolution, Stellar Populations Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

152.01 – Stellar Populations of 16 Galaxies from the Hubble Space Telescope WFC3/IR Surface Brightness Fluctuation Observations

Hyun-chul Lee[1], Victoria Le Grice[1], John P. Blakeslee[2], Joseph B. Jensen[3], Young-Wook Lee[4]
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We estimate the luminosity-weighted ages of 16 early-type galaxies in Virgo and Fornax clusters based upon the near-IR (F110W and F160W) SBF observations using the Hubble Space Telescope (HST). We compare the HST observations with the stellar population synthesis models using the Padova and the Teramo isochrones, respectively. We investigate and present how the alpha-element enhancement and the convective core overshoot affect the mean age and star formation history estimation.

152.02 – The Massive Star Population in M101

Skyler Grammer[1], Roberta M. Humphreys[1]
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An increasing number of non-terminal giant eruptions are being observed by modern supernova and transient surveys. But very little is known about the origin of these giant eruptions and their progenitors, many of which are presumably very massive, evolved stars. Motivated by the small number of progenitors positively associated with these giant eruptions, we have begun a survey of the evolved massive star populations in nearby galaxies. The nearby, nearly face on, giant spiral M101 is an excellent laboratory for studying a large population of very massive stars and their environments. Using archival Hubble Space Telescope (HST) Advanced Camera For Surveys (ACS) data, we have produced a catalog of luminous stars with photometric errors <10% for V < 24.5 and 50% completeness down to V = 26.5 even in regions of high stellar crowding. Using the HST/ACS catalog, we have examined the 100 Myr star formation history (SFH) of the massive star population in M101. We examine how the build up of stars over the last 100 Myrs has proceeded both radially in the disk, and in the spiral arms and inter- arms. Our results indicate the presence of a radial age gradient in the disk with the youngest stars occurring at smaller radii. Comparing the SFHs in the arms to the inter-arms, we find that the star formation rates (SFR) are higher in the arms, by ? 1 dex, over the 100 Myr time. The cumulative star formation functions in the arm and inter-arms do not differ appreciably suggesting the arm and inter-arm populations have evolved coevally. We have determined the light curves for a large sample of the massive stars in M101 from the Large Binocular Telescope (LBT) nearby galaxy monitoring program. We have also obtained spectra of the visually brightest and most luminous variable sources with the multiple object spectrograph Hectospec on the Multiple Mirror Telescope and with the Multiple Object Dual Spectrograph on the LBT.

152.03 – Profiling Andromeda's Metal Poor Population

Dylan Gregersen[1], Anil Seth[1], Julianne Dalcanton[2], Benjamin F. Williams[2], Claire Dorman[3], Puragra Guhathakurta[3]
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Contributing teams: The PHAT Team

The Andromeda galaxy is a nearby and unique laboratory for exploring galaxy morphology and evolution. The Panchromatic Hubble Treasury Survey (PHAT) has obtained six-band photometry for millions of resolved stars in Andromeda. Covering approximately a third of Andromeda, including the 10 kiloparsec ring, the PHAT survey provides data for studying the underlying galactic morphology. The structure of Andromeda's metal poor stellar component is of particular interest because it traces the early history and recent merging history. We identify metal poor stars in the survey using the PHAT photometry and spectroscopy from the Keck/DEIMOS. For several thousands of stars with line-of-sight velocities from spectroscopy, we are able to isolate photometric subspaces for metal poor and halo populations. These subspaces are then applied to the entire PHAT data set to expand the total number of stars in our analysis. We characterize the contamination due to crowding, photometric errors and reddening. We can then create density profile maps to test for the presence of stellar streams and other remnants of dwarf galaxy accretion.

152.04 – The Main Sequence Turnoff Age of the Metal Rich Open Cluster NGC 6253

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The open cluster NGC 6253 is an ideal cluster to analyze the formation and evolution of stars in a metal rich environment. Since this cluster is in the Southern Hemisphere it has not been as well studied as similarly high metallicity clusters, such as NGC 6791. We have obtained images of this cluster from the 0.9-meter telescope at the Cerro Tololo Inter-American Observatory (CTIO). Our principle goal in this study is focused on determining the cluster's main sequence turnoff age. This research complements a new data set of deep images of this cluster taken by the Gemini-South telescope, intended to study how white dwarf stars form in such a high metallicity environment.

152.05 – High Resolution Spectroscopic Measurements of Stars in the Milky Way

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Elements heavier than zinc are formed in stars through a nuclear process called neutron capture. This can be a rapid (r) or slow (s) process. Although both processes occur in the late stages of stellar evolution, they occur in different types of dying stars. The sites for creation of r-process and s-process elements are massive supernovae and the asymptotic giant branch (AGB), respectively. There is a relationship between the ratio of europium to barium, [Eu/Ba], in a star to the relative contributions of the r- and s-processes and therefore the nucleosynthetic contributions from supernovae versus AGB stars. This study focuses on Eu, Ba, and Fe abundances in six Milky Way stars with high-resolution spectroscopy. The relative contributions of the r- and s-process for the six sample stars were determined from the Eu and Ba abundances. The results show that all the stars sampled in this study obtained their elements heavier than zinc primarily from the r-process. Because metallicity ([Fe/H]) and age are correlated, our results provide a lower limit to the metallicity at which the products of AGB stars began to outnumber the products of massive supernovae.

152.06 – The Evolving Mixture of Barium Isotopes in Milky Way Halo Stars

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Heavy metals in stars form through one of two types of neutron capture processes: the rapid r-process or slower s-process. The fraction of odd and even barium isotopes in stars can indicate which process predominantly contributed to a star's heavy metals, since odd barium isotopes predominantly form through the r-process and even barium isotopes through the s-process. The "stellar model" predicts that older stars contain comparable amounts of odd and even barium isotopes, while the "classical model" states that they almost exclusively contain odd isotopes. This study investigated these competing models by analyzing high-resolution spectra of twelve Milky Way stars. These spectra were analyzed for the first time in this study. To quantify r- and s-process enrichment, we measured the odd barium isotope fraction in the stars by fitting models to the stars' spectra. Generating models involved measuring the stars' Doppler shift, resolution, and barium abundance. To reduce error margins we optimized resolution and barium abundance measurements by enhancing existing techniques through several rounds of revisions. Our results support the stellar model of heavy metal enrichment, and our proposed optimizations will enable future researchers to obtain a deeper understanding of chemical enrichment in the Universe. This research was supported by the Science Internship Program at the University of California Santa Cruz, Lick Observatory, and the National Science Foundation.

152.07 – Stellar Isotopic Abundances in the Milky Way: Insights into the Origin of Carbon and Neutron-Capture Elements

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Elements heavier than iron are formed by the capture of neutrons onto lighter nuclei. Neutron capture happens via two separate processes: the rapid neutron capture process (r-process) that occurs in supernovae, and slow neutron capture process (s-process) that occurs in less-massive stars. This work used high-resolution spectroscopy, synthetic model spectra, and a least-squares fit to show that the ratio of 12C to 13C increases proportionally with [Fe/H]. The new results agree with the conclusions of Lucatello et al. (2006) and Frebel (2008), and show significant improvement that contains less scattering of data points. Analysis of the obtained isotope ratios suggests that the carbon in most stars of the sample originated in supernovae. This paper also presents a method to calculate the europium isotope ratio by modeling the shapes of absorption lines. The range of europium isotopic ratios agrees with previous theoretical predictions about the classical model of heavy element nucleosynthesis, and the work presents new insight into the origins of life in the universe. We thank the US National Science Foundation, the UCSC Science Internship Program, and the Lick Observatory where the spectra were obtained.

152.08 – Fluorine in the Local Thin Disk

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The abundance of fluorine in stars in the Galactic thin disk have been obtained from observations of the 2.34 micron HF feature using the Phoenix infrared spectrometer on the KPNO 2.1-m telescope . The program focused on normal stars in evolutionary stages before the double-shell-burning AGB phase and which are not contaminated by the products of AGB nucleosynthesis. These data suggest that the abundance of fluorine increased linearly with iron in the metallicity range from -0.4<[Fe/H]<0.2 in the thin disk. While enhancements of the element in AGB stars clearly indicate that fluorine is produced in situ during double-shell burning, observations of normal stars suggest that the relative contribution of AGB stars to the Galactic fluorine abundance may be modest compared to the contributions from supernovae (and possibly Wolf-Rayet stars).

152.09 – Ages of Solar Neighborhood Stars Using APOGEE

Diane Feuillet[1], Jon A. Holtzman[1], Leo Girardi[2, 3], Carlos Allende-Prieto[4, 5], Timothy C. Beers[6], Katia M. Cunha[7], Damian Fabbian[4], Peter M. Frinchaboy[8], Michael R. Hayden[1], Steven Majewski[9]

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The SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE) is a high resolution (R ~23,000) near-IR (H-band) spectroscopic survey of 100,000 Milky Way stars designed to chemically trace the formation and evolution of Galactic stellar populations. In addition to the primary survey, the APOGEE spectrograph has been fitted with 10 fibers from the robotically controlled NMSU 1 m telescope to maximize the use of this instrument when not on sky with the Sloan 2.5 m telescope. This allows for single object observations with this high resolution NIR spectrograph. Using this new capability provided by the 1 m, we are conducting a survey of bright stars (H < 8) with accurate Hipparcos parallax measurements (μ_err < 10%), which are not accessible to the main APOGEE survey. These data can be reduced and analyzed in the same way as main survey data, resulting in detailed chemical information for hundreds of nearby stars. The atmospheric parameters combined with the Hipparcos distances allow for age estimates of these stars. We present initial age estimates from isochrone matching to Padova isochrones, and an age-metallicity relation for the current sample.

152.10 – Carbon Enhanced Stars in the Sloan Digital Sky Survey

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Carbon-enhanced stars are excellent probes of the nucleosynthesis history of the universe. The existence of carbon-enhanced stars that also show enhancement of s-process elements, such as barium, suggest that enhancements are initially produced in asymptotic giant branch stars which overflow their Roche lobes and deposit processed elements on to a lower mass binary companion. This process is also one mechanism for producing binary mass transfer, blue stragglers (BS). A second is mass transfer from a first ascent red giant companion. It is therefore expected that some percentage of BS stars (those produced from AGB companions) will show both carbon and barium enhancements. For this study we have chosen SDSS stars in the temperature range of 6000 K $\leq$ T_eff $\leq$7000 K. This range samples the halo main-sequence turn-off (MSTO) and BS stars just blueward of MSTO. We make use of measurements of the CH G-band strength, located at ~4330 Å, to estimate the stellar carbon abundance. To measure the G-band strength we use the S magnitude index, optimized by Martell et al. (2008). We run the same index measurements on a grid of synthetic spectra with Teff, Log(g), [Fe/H] and various carbon enhancements. Using the observed S-index and spectral parameters from Segue Stellar Parameter Pipeline, we compare to our calibration grid and determine the carbon abundance. We will present our carbon abundance results along with a rough estimate of barium from our index method and a classification into three broad groups, 1) No enhancement in Ba or C, 2) C enhancement and no Ba enhancement, and 3) C and Ba enhancement. We will present preliminary results on the percentages of each category for both the MSTO and BS stars.

152.11 – Comparison of Frequency of Carbon-Enhanced Metal-Poor Stars in SDSS/SEGUE with Binary Population Synthesis Models

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Contributing teams: the SEGUE Collaboration

We present a comparison of the frequencies of carbon-enhanced metal-poor (CEMP) giant and main-sequence turnoff stars from the Sloan Digital Sky Survey (SDSS) and the Sloan Extension for Galactic Understanding and Exploration (SEGUE) with predictions from asymptotic giant-branch (AGB) mass-transfer models. We consider two initial mass functions (IMFs) -- a Salpeter IMF, and a mass function peaked at 10 solar masses. In order to derive more accurate estimates of the CEMP fractions for stars in the Milky Way, we make use of SDSS/SEGUE main-sequence turnoff stars, which unlike giants are not expected to have experienced significant surface dilution. We also derive a correction function to compensate for the resulting undercounts of CEMP stars, due to the much weaker CH G-bands for warm, metal-poor turnoff stars. The comparisons indicate good agreement between the observed CEMP fractions for stars with [Fe/H]>-1.5, and a Salpeter IMF, but not with an IMF with higher characteristic mass. Thus, while the adopted AGB model works well for low-mass progenitors, it does not for high-mass progenitors. Our results imply that the IMF shifted from the high- to low-mass dominated in the early history of the Milky Way, which appears to have occurred in between [Fe/H]=-2.5 and [Fe/H]=-1.5. The corrected CEMP frequency for the turnoff stars with [Fe/H]<-3.0 is much higher than the AGB model prediction from the high-mass IMF, supporting previous assertions that one or more additional mechanisms other than AGB stars are required for the production of carbon-rich material below [Fe/H]=-3.0.

152.12 – Search for Carbon-Rich Asymptotic Giant Branch Stars in Milky Way Globular Clusters

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From our current understanding of stellar evolution, it would not be expected to find carbon rich asymptotic giant branch (AGB) stars in Milky Way globular clusters. Due to the low metallicity of the population II stars making up the globular clusters and their age, stars large enough to fuse carbon should have already evolved off of the asymptotic giant branch. Recently, however, there have been serendipitous discoveries of these types of stars. Matsunaga et al. (2006) discovered a Mira variable in the globular cluster Lynga 7. It was later confirmed by Feast et al. (2012) that the star is a member of the cluster and must be a product of a stellar merger. In the same year, Sharina et al. (2012) discovered a carbon star in the low metallicity globular cluster NGC6426 and reports it to be a CH star. Five more of these types of stars have been made as serendipitous discoveries and have been reported by Harding (1962), Dickens (1972), Cote et al. (1997), and Van Loon (2007). The abundance of these types of carbon stars in Milky Way globular clusters has been unknown because the discovery of these types of objects has only ever been a serendipitous discovery. These stars could have been easily overlooked in the past as they are outside the typical parameter space of galactic globular clusters. Also advances in near-infrared instruments and observing techniques have made it possible to detect the fainter carbon stars in binary systems. Having an understanding of the abundances of carbon stars in galactic globular clusters will aid in the modeling of globular cluster and galaxy formation leading to a better understanding of these processes. To get an understanding of the abundances of these stars we conducted the first comprehensive search for AGB carbon stars into all Milky Way globular clusters listed in the Harris Catalog (expect for Pyxis). I have found 128 carbon star candidates using methods of comparing color magnitude diagrams of the clusters with the carbon stars of the Large Magellenic Clouds and picking out very red stars in the red giant branch range. Observations will need to be done of these candidates to further confirm if they are carbon stars and are members of their respective globular cluster.

152.13 – They Might Be Giants: Using Kepler Data to Classify the Evolutionary State of Red Giant Stars

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Utilizing Kepler long cadence data from quarters 4 through 11, a blind study was performed of the long period (>1 day) variability of 200 giant stars previously identified as hydrogen shell burning (Red Giant Branch – RGB) giants or helium core burning (Red Clump) giants by the Bedding et al. (2011) asteroseismology study. By focusing on periods between 1 and 30 days, a relationship was found between the amplitude of the strongest period and the red giant evolutionary state. A second blind test using this diagnostic was able to correctly predict the evolutionary state of the red giants -RGB or Red Clump - with

74% accuracy. The goal was to find a diagnostic that would allow for ground based differentiation, but the typical amplitudes were less than 0.5 mmag. Understanding this difference may lead to better understanding of the red giant evolutionary process. This research made use of the NASA Exoplanet Archive and was made possible through the NASA/IPAC Training in Archival Research Project (NITARP), funded by NASA Astrophysics Data Program and Archive Outreach funds.

152.14 – Characterizing the Protostars in the Herschel Survey of Cygnus-X

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Contributing teams: Herschel Cygnus-X group

The Cygnus-X complex is an extremely active region of massive star formation at a distance of ~1.4 kpc which can be studied with higher sensitivity and less confusion than more distant regions. The study of this region is important in improving our understanding of the formation processes and protostellar phases of massive stars. A previous Spitzer Legacy survey of Cygnus-X mapped the distributions of Class I and Class II YSOs within the region and studied the interaction between massive young stars and clusters of YSOs. Using data from the recent Herschel survey of the region, taken with the PACS and SPIRE instrument (70-500 microns), we are expanding this study of star formation to the youngest and most deeply embedded objects. Using these data we will expand the sample of massive protostars and YSOs in Cygnus-X, analyze the population of infrared dark clouds and their embedded objects, construct Spectral Energy Distributions (SEDs) using pre-existing Spitzer and near-IR data sets (1-500 microns), and fit these sources with models of protostars to derive luminosities and envelope masses. The derived luminosities and masses will enable us to create evolutionary diagrams and test models of high-mass star formation. We will also investigate what role OB associations, such as Cyg OB2, play in causing subsequent star formation in neighboring clouds, providing us with a comprehensive picture of star formation within this extremely active complex.

152.15 – X-ray Constraints on Magnetic Activity and Star Formation Associated with the Red Supergiant VY CMa

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Magnetic field strengths inferred from maser observations of the optically thick circumstellar envelope enshrouding the red supergiant VY CMa indicate that its stellar surface fields may be capable of producing coronal X-ray emission. Evidence for episodic yet randomly directed mass ejections from VY CMa, coupled with the magnetism inferred from maser emission, further suggests that magnetic surface activity may play a fundamental role in mass loss from the red supergiant. Motivated by this evidence, we obtained X-ray observations of a field centered on VY CMa with the XMM-Newton X-ray Observatory in May of 2012. VY CMa is not detected in the ~20 ks XMM exposure. We have determined the upper limit on the X-ray flux of VY CMa as a function of assumed source plasma temperature and intervening absorption, and we use these results to constrain the level of surface magnetic activity on VY CMa at the epoch of the XMM observation. We also detected over a hundred X-ray emitting field sources within ~15' of VY CMa. Via cross-correlation of these sources with optical and infrared catalogs, we identify a few dozen X-ray sources that have stellar counterparts. Comparison with theoretical pre-main sequence (pre-MS) isochrones suggests most of these newly discovered X-ray-emitting stars in the immediate vicinity of VY CMa may be late-type, pre-MS stars at the approximate distance of the famous supergiant itself. We consider whether these stars may constitute a loose association that is coeval with VY CMa, and we discuss the potential relationship of this putative "VY CMa Association" to other nearby regions of recent star formation, including the young cluster NGC 2362.

152.16 – Study of the Impact of Stellar Multiplicity on Planet Occurrence and Properties

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Stellar multiplicity in an exoplanet host star system is likely to affect planetary formation and evolution. To explore this possibility, we used visible-light adaptive optics to search for the presence of possible bounded stellar companions to known exoplanet host stars. Here we present the results and analysis of 48 exoplanet host stars as imaged by the Robo-AO system on the 1.5-m telescope at Palomar Observatory. For each object, we performed a search for the presence of stellar companions using several techniques, and for each method we assessed its detection limits. Finally, we address the questions

of sensitivity, density number, and spectral types of stellar companions from a statistical standpoint, and conclude on the impact of stellar multiplicity to exoplanet host stars.

152.17 – Finding the Elusive Substellar Members of Young Moving Groups

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Substellar members of young moving groups (YMGs) are valuable benchmarks to empirically define brown dwarf evolution with age and to study the lowest mass end of the initial mass function. While there has been significant progress in the past ~15 years in identifying the stellar members of YMGs, the cool, substellar members have remained elusive as only 5 are known. We have combined Pan-STARRS-1 (PS1) proper motions with optical-NIR photometry from PS1 and 2MASS to increase the search volume for these missing substellar YMG members (~0.01-0.08 M_{sun}) by a factor of ~50-100. PS1 is uniquely suited for a systematic search because of its large-area sky coverage and precise astrometry. We have identified candidate young brown dwarf members using a combination of color selection, spectral energy distribution fitting and proper motion analysis. Furthermore, we have obtained NIR spectra of several candidate substellar members and spectroscopically confirmed their youth.

152.18 – Population III Stars: Evolution and Explosions

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We present evolution calculations for the evolution for 15 M™ to 40 M™ Pop III stars from pre-main sequence to very near core collapse. Further we use the final structure of our evolution models to calculate resulting supernovae light curves using a 1-D radiation hydrodynamics code. We present light curves both unattenuated and attenuated using k-corrections to account for dimming due to large cosmological redshifts at z = 15. We will also discuss preliminary results for low mass, Z=0, evolution calculations.

153 – Pulsars & Neutron Stars Poster Session
Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

153.01 – Searching for Millisecond Pulsars in Fermi Unidentified Gamma-Ray Sources

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For five years, the Large-Area Telescope (LAT) aboard the Fermi spacecraft has been collecting gamma-ray photons from every corner of the sky in hopes of identifying high-energy objects such as Active Galactic Nuclei (AGN) and Millisecond Pulsars (MSPs). Probing unidentified Fermi sources with MSP-like spectra has been a highly successful method for discovering new MSPs. Boasting a success rate of around 20%, large radio telescopes such as the GBT, Parkes, and GMRT had collectively found nearly 50 new MSPs in just three and a half years of searching. In this study, we point to 34 unidentified Fermi sources using the Arecibo radio telescope at 327 MHz, observing the objects in 15-minute intervals three times each. Thus far, the search at Arecibo has led to the discovery of four new MSPs with periods ranging from 1.99 to 4.07 ms. Additionally, observations of Fermi sources made with the Parkes radio telescope have been analyzed, yielding three new MSPs. Included among the new discoveries is an MSP with an exceptionally high dispersion measure (DM)-to-period ratio, and two highly accelerated MSPs (possibly in eclipsing binaries with orbital periods shorter than one day). After completing all planned observations, the discovered MSPs will be timed in order to enable the folding of the sparse gamma-ray photons collected via the LAT modulo the period observed at radio frequencies.

153.02 – The Second Fermi Large Area Telescope Catalog of Gamma-ray Pulsars

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Contributing teams: Fermi Large Area Telescope Collaboration, Pulsar Timing Consortium, Pulsar Search Consortium

Using three years of survey data and enhanced analysis techniques, the second Fermi Large Area Telescope (LAT) catalog of gamma-ray pulsars details spectral and light-curve characteristics of 117 rotation-powered pulsars observed above 0.1 GeV. The known gamma-ray pulsars are separated into three classes: young radio-loud, young radio-quiet, and millisecond pulsars. We look for trends in the population of LAT-detected pulsars and compare the gamma-ray properties to those at radio, optical, and X-ray wavelengths. In addition, we provide gamma-ray flux upper limits, assuming a pulsar-like point source, over the entire sky. Auxiliary files with pulsar properties, light curves, and spectra are provided through the Fermi Science Support Center. Portions of this work performed at the Naval Research Lab are sponsored by NASA DPR S-15633-Y.

153.03 – Bowshock Hunting: an All Sky Survey of Fermi-Pulsars to Catalogue Hα Bowshocks

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Most of the handful of known Hα bowshock nebulae are produced by Fermi-detected energetic pulsars, both young objects and millisecond pulsars. These shocks are both rare and beautiful, and their study can provide important insight into pulsar emission, non-radiative shock physics and the constitution of the ISM. We report on an all-sky Hα survey of 103 Fermi pulsars with a relatively uniform sample selection and high sensitivity, constituting the largest and most sensitive search for pulsar Hα bowshocks to date. We have confirmed our sensitivity by re-imaging several known bowshocks (around PSRs J0437-4715, J0742-2822, J1741-2054, J2124-3358). Our observations of the faintest of these known shocks (around young pulsar J0742-2822 and millisecond pulsar J2124-3358) produce images more sensitive than existing data and reveal previously unobserved Hα structure. We report the discovery of one additional Hα bowshock around the LAT gamma-ray PSR J2030+4415. The new nebula has a symmetric apex structure near the pulsar and an unusual bubble structure around the tail, giving new information on the pulsar proper motion and distance. Even with our survey's high sensitivity, an additional 98 targets (most imaged for the first time) show no conclusive evidence of an Hα bowshock. We use our data to quantify an upper bound of the Hα flux for each source and to scale this bound with source surface brightness and angular size. We use these limits and the available parameters of individual pulsars to constrain the neutral hydrogen content of the ISM surrounding each object. Our survey thus supplies a spot-sampled census of HI in the local Milky Way and emphasizes the rarity of conditions required to produce an Hα bowshock.

153.04 – A Case Study of Three NANOGrav Millisecond Pulsars

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Contributing teams: NANOGrav Collaboration Timing Group

The primary goal of the North American Nanohertz Observatory for Gravitational waves (NANOGrav) is to detect and study gravitational waves through the precise timing of millisecond pulsars. Fitting for a number of extrinsic and intrinsic effects to determine a `timing model' is necessary to detect the small perturbations in arrival times due to gravitational waves. Here we outline the methodology used for and solutions obtained from timing of three recently discovered millisecond pulsars. Two sources were discovered in searches of Fermi unidentified sources: J0340+4130, an isolated pulsar, and J2302+4442, a low-eccentricity binary. The third was discovered in an Arecibo survey: J1903+0327, a binary pulsar in an unusual eccentric (e=.44) orbit. We also discuss the millisecond pulsar properties required for inclusion in the NANOGrav pulsar timing array, and how these new sources compare with other NANOGrav pulsars.

153.05 – Creation of a galactic millisecond pulsar database

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There are over 200 known Galactic millisecond pulsars which are defined in this study as pulsars with spin periods < 30ms. They are thought to originate from low-mass X-ray binary systems. This study involved the collection of profiles of millisecond pulsars found in the Milky Way galaxy whose pulse period ranges between 1.4 and 30 milliseconds. We used a variety of resources to obtain the needed data of these pulsars. Once obtained, we created pulse profiles of each pulsar. Using the pulse profiles, we then used a computer program to fit Gaussian curves to the profile applying components with different widths, heights, and centers. The result of this study will be the creation of an online database of Galactic millisecond pulsars which will include graphs of the pulse profile of each pulsar and a text table of the components used to fit the profile. Millisecond pulsars are being used to form a Galactic-scale observatory to search for gravitational waves.

153.06 – Population Synthesis of Radio & Gamma-Ray Millisecond Pulsars

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In recent years, the number of known gamma-ray millisecond pulsars (MSPs) in the Galactic disk has risen substantially thanks to confirmed detections by Fermi Gamma-ray Space Telescope (Fermi). We have developed a new population synthesis of gamma-ray and radio MSPs in the galaxy which uses Markov Chain Monte Carlo techniques to explore the large and small worlds of the model parameter space and allows for comparisons of the simulated and detected MSP distributions. The simulation employs empirical radio and gamma-ray luminosity models that are dependent upon the pulsar period and period derivative with freely varying exponents. Parameters associated with the birth distributions are also free to vary. The computer code adjusts the magnitudes of the model luminosities to reproduce the number of MSPs detected by a group of ten radio surveys, thus normalizing the simulation and predicting the MSP birth rates in the Galaxy. Computing many Markov chains leads to preferred sets of model parameters that are further explored through two statistical methods. Marginalized plots define confidence regions in the model parameter space using maximum likelihood methods. A secondary set of confidence regions is determined in parallel using Kuiper statistics calculated from comparisons of cumulative distributions. These two techniques provide feedback to affirm the results and to check for consistency. Radio flux and dispersion measure constraints have been imposed on the simulated gamma-ray distributions in order to reproduce realistic detection conditions. The simulated and detected distributions agree well for both sets of radio and gamma-ray pulsar characteristics, as evidenced by our various comparisons.

153.07 – Population Synthesis of Double Neutron Stars

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Globular clusters in our galaxy provide a fertile ground for stars to undergo supernova which leads to the creation of neutron stars. A population synthesis was created to study the population of double neutron stars (DNS) in our Galaxy that originated in globular clusters. The rate of DNS formation is proportional to the cluster's luminosity and the resulting kick from the supernova at birth ejects the DNS from the cluster. Initial conditions are given to the DNS after being ejected and allowed to evolve throughout the galaxy to the present time. With a simulated population of DNS we test to see how many of them are detectable from Earth with radio telescopes. DNS are being used as a way to detect gravitation waves when the two neutron stars spiral into each other. A better constraint on their formation and existence will lead to more accurate predictions for gravitational wave detectors.

153.08 – Timing PSR J0453+1559: A likely asymmetric double neutron star system

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PSR J0453+1559 is a pulsar with a spin period of 45.7 ms discovered in the Arecibo All-Sky 327 MHz Drift Pulsar Survey. Subsequent observations of this source performed at the Arecibo Radio Observatory has revealed that it is in a binary system with an orbit period of 4.07 days with an eccentricity of 0.1125. The semi-major axis of the orbit is 14.5 light seconds, which implies, for a pulsar mass of 1.35 solar masses, a minimum and median companion mass of 1.0 and 1.2 solar masses respectively. This strongly suggests this is a new double neutron star (DNS) system. If confirmed, this would be the tenth DNS known in the Universe.

153.09 – A Bayesian Approach to Pulsar Timing

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Efforts are underway worldwide to use timing observations of an array of millisecond pulsars to detect low-frequency gravitational waves (GWs). In order to detect the tiny timing delays induced by GWs, we need to be able to model the time of arrivals (TOAs) very accurately, down to a few to tens of nanoseconds. We present a new method for fitting observed TOAs to timing models that uses Bayesian inference. Using Bayesian inference allows us to incorporate information from other observations (ex. distances from measurements of the DM and maps of the ISM) in the form of priors on the model parameters, and provides a way to include models of intrinsic pulsar noise in the timing model. We compare the results of our method with timing solutions found using a conventional least-squares linear fit.

153.10 – An Analysis of Models of Black Hole – Neutron Star Binary Systems

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Black hole – neutron star (BHNS) binaries are a holy grail of physics. Their discovery will provide astronomers with a new laboratory to hunt for gravitational waves. This study looked at theoretical models of BHNS binary systems and aimed to predict the number of BHNS systems potentially detectible with present and future radio telescopes. Collaborators provided two models of the galactic BHNS population, a "worst-case scenario" and a "best-case scenario". We then provided each BHNS system in each model with parameters based on known distributions of period, pulse width, magnetic field strength, pulse orientation, luminosity, galactic coordinates, and spectral index. Our results show that the number of potentially detectable systems with current radio telescopes is between 0 and 100, and that the number of potentially detectable systems with planned future telescopes could reach as many as 2000. Considering that no BHNS binary systems have yet been detected, our results are consistent with observations up to the present.

153.11 – 2003 VLA Archival Data Search for Fast Radio Bursts

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Contributing teams: Sarah Burke-Spolaor, Joseph Lazio

We present a search for fast radio bursts (FRBs) in legacy VLA Archival data from June 2003 at 330MHz, motivated by the recently published 2013 Thornton et al. paper on the discovery of four millisecond long FRBs in archival Parkes Observatory data. Our two candidates do not exhibit any periodic behavior and are uncorrelated with known nearby radio emitting sources. The candidates are also located within a few arcsecond of cataloged galaxies. In both cases, we have split the data in frequency and confirmed that the candidates are visible in both frequency sub-bands. Furthermore, we have used a threshold of 6.5 standard deviations indicating these candidates are unlikely to be background noise or instrumental error. If these two candidates prove to be FRBs they can serves as evidence that FRBs are not localized or somehow related to the Parkes observatory from which all FRB have been reported so far and should motivate further studies of archival data to better understand the distribution of these events. This research was carried out at the Jet Propulsion Laboratory, California

153.12 – A Search for Fast Radio Transients with LWA-1

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A low-frequency single dispersed pulse search was recently conducted with the first station of the Long Wavelength Array (LWA-1), a low-frequency radio telescope located near Socorro, NM, which is sensitive to a frequency range of 10-88 MHz. Possible candidate progenitors for such signals include: compact object mergers, supernovae, cosmic string cusp events, and exploding primordial black holes. I will summarize the observations conducted, the method used to reduce the data collected, and some relevant limits which can be set as a result of this work.

153.13 – New Results from the AO327 Drift Pulsar Survey

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The Arecibo 327 MHz drift pulsar survey (AO327) has operated since 2010 and aims to cover the entire Arecibo sky (declinations of -1 to 38 degrees). We present details on the progress of the survey and a new set of discoveries over the past year. Phase 1 of AO327 targets declinations of -1 to 28 degrees and is 55% complete; Phase 2 will target declinations of 28 to 38 degrees. The survey is expected to be completed in 2017. Out of a total of 28 new pulsars, 12 were found in 2013, including three millisecond pulsars. PSR J2234+06 has a rotation period of 3.58 ms and is in a 32-day orbit in a binary system with a white dwarf companion. This pulsar is bright and a very stable rotator, making it suitable for inclusion in Pulsar Timing Arrays. The orbit of J2234+06 has an eccentricity of 0.13, which cannot be accounted for by stellar evolution but may be explained by an origin in a subsequently disrupted hierarchical triple, or by an exchange interaction. PSR J0509+08 has a period of 4.06 ms and is in a 4.9-day binary system with a white dwarf companion. This pulsar is also a candidate for inclusion in PTAs.

153.14 – Pulsar Search Results from the Arecibo Remote Command Center

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Contributing teams: GBNCC Consortium, PALFA Consortium, GBTDrift Consortium, AO327 Consortium

The Arecibo Remote Command Center (ARCC) at the University of Texas at Brownsville, in collaboration with various Universities, is currently engaged in searching through ongoing radio telescope surveys for radio pulsars. ARCC is an integrated research/education program that allows students at the high school and undergraduate level to be directly involved with the research at the Arecibo and Green Bank radio telescopes. We discuss the progress of our search effort with PRESTO pulsar search pipelines. Web based tools have been developed so that high school, undergraduate, and graduate

students could rank the pulsar candidates created by PRESTO pipelines. We describe these tools and present our current discoveries.

153.15 – I(don't)C 10: An Attempt to Find Pulsars in the Starburst Galaxy IC 10

Hind Al Noori[1], Mallory Roberts[1, 2], David Champion[3], Maura McLaughlin[4], Scott M. Ransom[5], Paul S. Ray[6]
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We conducted a deep search of the irregular blue compact dwarf galaxy IC 10 in search of potential radio pulsars. To date the only extragalactic pulsars detected have been found in the Magellanic Clouds; however as a galaxy that is in many ways similar to (and has a higher star formation rate than) the Small Magellanic Cloud, IC 10 may also be home to some detectable pulsars. Yet it is also important to take into account IC 10's poorly known distance that may be 10 to 15 times greater than that of the SMC. We made three separate observations for a total of 16 hours (the longest of which was 6 hours) at 820 MHz with the Green Bank Telescope using the GUPPI backend that yielded a bandwidth of 200 MHz and a time resolution of 204.8 μs. The data was searched up to a DM of 2000 and an acceleration zmax of 50 using the PRESTO software package. However, we were unable to identify any continuous pulsed signals, to which we had a flux density sensitivity of 0.015 mJy, or giant single pulses, to which our sensitivity for a 10ms pulse at 5-sigma sensitivity was 20mJy. Our findings support the hypothesis that IC 10 has had a very recent burst in star formation, as is evidenced by the exceptionally high number of Wolf-Rayet stars, which have not yet resulted in a correspondingly high supernova rate, and is suggested by the lack of supernova remnant detections in the galaxy.

153.16 – Developing Precision Pulsar Timing Capability for the DSN

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Millisecond pulsars are a class of radio pulsars with extremely stable rotations. The excellent timing stability of millisecond pulsars can be used to study a wide variety of astrophysical phenomena. In particular, observations of a large sample of these pulsars can be used to detect the presence of low-frequency gravitational waves. We are currently developing a precision pulsar timing backend for the Deep Space Network (DSN), which will allow the use of short gaps in tracking schedules to observe and time pulses from an ensemble of millisecond pulsars. The NASA Deep Space Network (DSN) operates clusters of large dish antennas (up to 70-m in diameter), located roughly equi-distant around the Earth, for communication and tracking of deep-space spacecraft. The backend system will be capable of removing entirely the dispersive effects of propagation of radio waves through the interstellar medium in real-time. We will describe our development work, initial results, and prospects for pilot observations scheduled later this year. This research was performed at the Jet Propulsion Laboratory, California Institute of Technology, under the Research and Technology Development Program, under a contract with the National Aeronautics and Space Administration.

153.17 – Recent Results on Pulse Jitter and Other Single Pulse Properties of Pulsar J1713+0747

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J1713+0747, a radio pulsar with a period of ~4.5ms, is routinely monitored by NANOGrav (the North American Nanohertz Observatory for Gravitational waves) because of a stable timing RMS of ~30ns that makes it a significant contributor to NANOGrav's gravitational wave (GW) detection campaign with Arecibo Observatory and the Green Bank Telescope. Other recent campaigns have yielded an abundance of single pulse data about this object, which, along with the other best timing pulsars in the NANOGrav pulsar timing array, are being studied for low-level but persistent contributions to the overall GW detection noise budget. We report on variations in pulse jitter occurring during baseband observations, and study correlations between jitter and pulse times-of-arrival. We also report on variations of these single pulse properties with scintillation caused by the signal's propagation through the interstellar medium. Finally, we discuss implications of these findings for the overall PTA effort.

153.18 – Rotation Measures of Globular Cluster Pulsars as a Unique Probe of the Galactic Magnetic Field

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As a linearly-polarized signal propagates through the interstellar medium, it rotates through an angle that is linearly proportional to its wavelength. The scaling factor is called the "rotation measure" (RM) and is a function of both the electron column density and the magnetic field strength along the line of sight to the source. We have measured highly-precise RMs for 25 of the 35 millisecond pulsars (MSPs) in the globular cluster Terzan 5, using Green Bank Telescope radio observations: a total of 86 hours at 1.5 GHz, and a total of 29 hours at 2 GHz. For each MSP, we calculate the weighted magnetic field strength along the line of sight to the source, using the ratio of RM to electron column density. We find a gradient in field strength of 15-20% across the cluster, indicating 0.1 µG fluctuations on parsec scales. This represents the first use of dense globular cluster pulsar populations as a probe of the small-scale structure of the galactic magnetic field.

153.19 – Observations of Giant Pulses from Pulsar B0950+08 using LWA1

Jr-Wei Tsai[1], John H. Simonetti[1], Michael Kavic[2], Sean E. Cutchin[3, 4], Namir E. Kassim[3], Jonathan Gough[2], Bernadine Akukwe[2], Brandon Bear[1]

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We report the detection of giant pulse emission from PSR B0950+08 at 40 MHz with the First Station of the Long Wavelength Array. 1029 pulses were detected in 24 hours of observations conducted between March and April 2012. The range of flux density is from ~50 Jy to ~300 Jy over a 16 MHz bandwidth for a ~10 millisecond pulse duration.

153.20 – Exceptional Flares from the Crab Nebula in the Fermi Large Area Telescope

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Contributing teams: The Fermi LAT Collaboration

The Crab Nebula continues to provide an enigmatic target for astrophysical studies. Current gamma-ray telescopes have opened a new chapter on Crab observations with detections of rapid and energetic flares that have not been found to have corresponding emission outside the MeV-GeV energy band. Fermi Large Area Telescope (LAT) measurements of flares with flux doubling times of ~6-8 hours and cutoffs in the photon spectrum above 300 MeV impose significant constraints on the origin and mechanism for the emission. The ongoing all-sky monitoring available from Fermi has enabled several LAT targets of opportunity accompanied by broad multiwavelength campaigns. I will review the LAT observations of the Crab and consider future prospects for the LAT to provide insight into where and how particles in the nebula are accelerated and generate the extreme gamma-ray variability.

153.21 – Chandra and Suzaku observations of two galactic TeV sources

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We present preliminary results from Chandra and Suzaku observations of the TeV sources HESS J1809193 and HESS J1741-302A. Multi-wavelength observations of the HESS J1809193 field reveal a complex picture. Although most of the bright TeV emission can be attributed to the pulsar-wind nebula of PSR J18091917, several supernova remnants, as well as another PWN, may contribute to the observed VHE emission. The H.E.S.S. image shows an extension toward north-east, which could be a separate TeV source. One of the X-ray sources in the north-east extension of HESS J1809193 is the low-mass X-ray binary candidate XTE J1810-189, for which we show the outburst history from multiple observatories. We also present analysis of the Fermi LAT data for both H.E.S.S. sources. Preliminary multi-wavelength classification is presented for the brightest X-ray sources in the fields of the two TeV sources. We investigate whether there is any correlation between the TeV emission and the sources seen at lower energies. This research was partially supported by NASA grants NNX10AH82G, NNX09AC81G, and NASA/SAO grant GO3-14049X.

153.22 – Gamma-ray and X-ray Properties of Pulsar Wind Nebulae and Unidentified Galactic TeV Sources

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During the past decade TeV gamma-ray observatories have revealed a large number of very-high energy (VHE) sources in the Galactic plane. Pulsar-wind nebulae (PWNe), shell-type supernova remnants (SNRs), and microquasar-type high-mass X-ray binaries (HMXBs) appear to be firmly established sources of the leptonic cosmic rays in our Galaxy. They account for about a half of the total number (~90) of Galactic VHE sources, with 28 PWNe, 10 SNRs and 5 HMXBs. There is also a large number of extended TeV sources positionally coincident with young energetic pulsars; in most cases they can be considered as TeV PWN candidates. Some of these associations are more secure than others (e.g., in those cases when X-ray PWNe have been detected). In addition, there remains a sizable fraction of unidentified VHE sources (~20). We summarise the TeV and X-ray properties of the population of Galactic VHE sources focusing on PWNe associations and unidentified TeV sources. For some of these sources, multi-wavelength observations suggest a possible counterpart (such as an SNR interacting with a molecular cloud, or a star-forming region), but most of these associations are still uncertain because at least some of these sources still could be powered by offset pulsars whose PWNe are faint in X-rays. Finally, there are "dark" VHE sources, for which neither radio nor X-ray images reveal any plausible counterparts.

153.23 – Can X-ray Observations Provide Accurate Pulsar Distances?

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X-ray observations are often used to estimate pulsar distances based on such things as the observed correlation between the spin down power and the X-ray luminosity, the fit value of the absorption, or thermal emission from an assumed surface area. However, none of these methods have been systematically tested against pulsars with accurately known distances. We will present initial results from a systematic analysis of archival X-ray data of pulsars which have well determined distances through parallax measurements. We will use these results to derive a new Lx-Edot relationship for both young and recycled pulsars, compare the measured nH to the Drimmel et al. (2003) 3D Galactic Extinction Model, and estimate the surface emission radii using both blackbody and neutron star atmosphere models.

153.24 – X-Ray Observations of PSR J0337+1715

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Contributing teams: The GBT Driftscan Collaboration

PSR J0337+1715 is a fast, bright, and so-far unique millisecond pulsar in a hierarchical triple system with two white dwarf (WD) companions. Here we report recent observations of this system with the XMM-Newton X-ray telescope. We have analyzed X-ray spectroscopy and optical/ultraviolet photometry. The X-ray data seem largely consistent with expectations for most millisecond pulsars. The optical/ultraviolet data help us determine the extinction and size of the inner WD companion as well as the affects of the outer, more massive WD. We discuss the implications of these data and prospects for the future.

153.25 – Orbital Phase-Resolved X-ray Observations of the Black-Widow Pulsar J1446-4701

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PSR J1446--4701 is a recently discovered radio and gamma-ray recycled pulsar in a tight binary (binary period $P_b = 6.6$ hr, $a\sin i = 1.7 R_\odot$). The relativistic pulsar wind at such close proximity is expected to evaporate the low mass companion ($M_{\rm min}= 0.019 M_\odot$), which should lead to an orbital phase dependence of the multiwavelength emission of this Black Widow pulsar (BWP) system. We observed the system with XMM-{\sl Newton} EPIC (0.3--10 keV) and Optical Monitor (B,V) for 60 ks, covering about 2.5 binary orbits, to look for the orbital variability of its flux and spectrum. The EPIC data do not show a significant orbital variability of the flux, perhaps due to a low orbital inclination. However, the orbital phase-resolved spectral analysis allowed us to separate two spectral components: thermal pulsar polar-cap emission ($kT=0.18\pm0.02$ keV, $R=216\pm60$ m), detected throughout the orbit, and a hard power-law component ($\Gamma = 1.4\pm0.6$), detected only for the half-orbit around superior conjunction of the pulsar. We infer the hard non-thermal

component to be the intra-binary shock emission. We did not detect an optical counterpart with the optical monitor, which sets some strong constraints on the companion. In the context of similar BWPs, we discuss the pulsar's high energy emission characteristics and intra-binary shock energetics.

153.26 – A Model for the Electrically Charged Current Sheet of a Pulsar

C. R. DeVore[1], Spiro K. Antiochos[1], Carrie E. Black[2, 1], Alice K. Harding[1], Constantinos Kalapotharakos[3, 1], Demosthenes Kazanas[1], Andrey Timokhin[4, 1]

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Global-scale electromagnetohydrodynamic solutions for the magnetosphere of a pulsar consist of a region of low-lying, closed magnetic field near the star bounded by opposite-polarity regions of open magnetic field along which the pulsar wind flows into space. Separating these open-field regions is a magnetic discontinuity – an electric current sheet – consisting of nonneutral plasma. We have developed a self-consistent model for the internal structure of this sheet by generalizing the charge-neutral Vlasov/Maxwell equilibria of Harris (1962) and Hoh (1966) to allow a net electric charge. The resulting equations for the electromagnetic field are identical for Maxwell (nonrelativistic) and Jüttner/Synge (relativistic) distribution functions of the particles. The solutions have a single sign of net charge everywhere, with the minority population concentrated near the current sheet and the majority population completely dominant far from the sheet. As the fractional charge imbalance at the sheet increases, for fixed relative drift speed and total thermal pressure of the particles, both the electric- and magnetic-field strengths far from the sheet increase. The electrostatic force acts to disperse the charged particles from the sheet, so the magnetic force must increase proportionately, relative to the charge-neutral case, to pinch the sheet together and maintain the equilibrium. The charge imbalance in the sheet that can be accommodated has an upper bound, which increases monotonically with the relative drift speed. In the limit of maximum charge imbalance and field strength, the density of majority particles asymptotically approaches a uniform value far from the sheet, rather than falling exponentially to zero as in the charge-neutral case. This model provides a rigorous starting point for investigating electromagnetohydrodynamic and kinetic instabilities that could lead to magnetic reconnection and current-sheet disruption in pulsar magnetospheres. Exploratory particle-in-cell simulations of some representative equilibria are presented in a companion paper at this conference (C. E. Black et al. 2014). This work was supported by NASA GSFC's Science Innovation Fund.

153.27 – Kinetic Simulations of the Electrically Charged Current Sheet of a Pulsar

Carrie Black[1, 2], Spiro K. Antiochos[2], C. R. DeVore[2], Alice K. Harding[2], Constantinos Kalapotharakos[3, 2], Demosthenes Kazanas[2], Andrey Timokhin[4, 2]

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The pulsar magnetosphere is believed to comprise a volume of low-lying, closed field about the magnetic equator, bounded by polar open-field regions in which the pulsar wind flows into space. In the standard global-scale models, a magnetic discontinuity (electric current sheet) of nonneutral plasma separates open field regions of opposite polarity. We use the particle-in-cell Plasma Simulation Code, PSC, to examine the dynamics of a self-consistent model for the internal structure of this sheet, in which the charge-neutral Vlasov/Maxwell equilibria of Harris (1962) and Hoh (1966) are generalized to allow a net electric charge. PSC accommodates both Maxwell (nonrelativistic) and Jüttner/Synge (relativistic) distribution functions for the electrons and positrons. Numerical equilibrium solutions to the 1D Maxwell equations are initialized on the 2D PSC grid, supplemented by periodic boundary conditions in the direction parallel to the sheet and insulating boundary conditions remote from the sheet in the perpendicular direction. As is typical in kinetic studies of pair plasmas, the particle thermal energy and the relative drift velocity driving the current are assumed to be of order the rest energy and the speed of light, respectively. In this limit, the Debye length, skin depth, and Harris/Hoh width of the current sheet are all comparable to each other, rather than widely separated and arranged in order of increasing size as typically occurs in nonrelativistic plasmas. The qualitatively new feature of our pulsar simulations is the equilibrium electric field, whose strength can be comparable to that of the magnetic field in the relativistic limit. We expect its presence to have profound consequences for the linear stability and nonlinear evolution of charged pulsar current sheets, especially with regard to tearing and reconnection of the magnetic field. Exploratory PSC simulations of magnetic reconnection in some representative "electrified Harris/Hoh" equilibria will be presented. The derivation, solution, and analysis of the equilibrium Vlasov/Maxwell equations are discussed in a companion paper at this conference (C. R. DeVore et al. 2014). This work was supported by NASA GSFC's Science Innovation Fund.

153.28 – Deep Chandra observations of pulsar tails: PSR B0355+54

Noel Klingler[1], Blagoy Rangelov[1], Oleg Kargaltsev[1], George G. Pavlov[2], Roger W. Romani[3], Patrick O. Slane[4]

1. George Washington University, Washington, DC, United States. 2. Pennsylvania State University, University Park, PA, United States. 3. Stanford University, Stanford, CA, United States. 4. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.
Contributing teams: The XVP PWN Collaboration

Pulsar wind nebulae (PWNe) are sources of nonthermal X-ray emission and prominent sites of particle acceleration. Among other parameters, the PWN appearance (and possibly other properties) depend on the pulsar velocity. If a pulsar moves with a supersonic speed, the ram pressure exceeds the ambient medium pressure, resulting in a bow-shock PWN with a tail behind the pulsar. Here we report on X-ray observations of the extended pulsar tail behind PSR B0355+54 carried out as a part of the Chandra XVP program (8 observations; 395 ks total exposure over a period of 8 months). To examine long-term variations, we also re-analyzed the archival data. We investigate the spatial and spectral properties of the compact nebula and of the extended tail. We also study the changes in the compact nebula for various timescales. The spectrum of the compact nebula is rather hard with the photon index ?=1.4+/-0.1, and we find a hint of only slow cooling along the tail (?? = 0.2) up to 5' from the pulsar. The compact nebula is variable on timescale of years and is likely to be variable on a timescale of months. These results are compared to those obtained for other pulsar tails such as that of PSR J1509-5850.

153.29 – Investigating Variability of Quiescent Neutron Stars in the Globular Clusters NGC 6440 and Terzan 5

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Using thermal emission from neutron stars to measure their radii is one of the most promising means of constraining the dense matter equation of state. This is often done by studying the X-ray spectra of transient neutron stars in quiescence. These quiescent neutron stars are best fit with a blackbody-like thermal component at energies below 2 - 3 keV, with a power-law component sometimes dominating harder energies. But, using their quiescent spectra to measure neutron star radii is complicated by the fact that they are sometimes seen to vary between observations. In order to further understand the variability in these systems we studied multiple Chandra observations of the quiescent neutron stars in the globular clusters NGC 6440 and Terzan 5. We found there was no strong evidence for variability in the thermal component in the objects we looked at, suggesting that radius measurements from these sources would be robust.

153.30 – Is SNR G12.8-0.0 Really Associated with Star Forming Region W33?

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The supernova remnant (SNR) G12.8-0.0 is believed to be associated with a nearby young star formation region W33 due to their proximity in the sky. This association suggests the distance of SNR G12.8-0.0 to be 4.5 kpc. We test this association by analysing recent XMM-Newton and Suzaku observations of this system, finding 0.5-2.0 keV emission in excess to that predicted by an absorbed power-law model fit to the observed 0.5-10 keV spectrum. The soft emission from the pulsar wind nebula (PWN) embedded in the SNR is consistent with our model fit to X-ray emission coincident with W33. Our results show very different N_H for the PWN and W33 emission, which suggests different distance for the SNR and the W33 stellar cluster.

154 – Novae, Cataclysmic Variables, Evolved Stars
Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

154.01 – The 100 year DASCH Transient Search

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The Digital Access to a Sky Century at Harvard (DASCH) project is currently digitizing the roughly 500,000 photographic plates maintained by the Harvard College Observatory. The Harvard plate collection covers each point of the sky roughly 500 to 3000 times from 1885 to 1992, with limiting magnitudes ranging from B=14-18 mag and photometric accuracy within ±0.1 mag. Production scanning (up to 400 plates/day) is proceeding in Galactic coordinates from the North Galactic Pole and is currently at roughly 50 degrees galactic latitude. The vastness of these data makes the DASCH project ideal to search for transient behavior. In particular, the large time base of the DASCH collection gives an unprecedented advantage when searching for outbursting systems with recurrence rates of decades or longer. These include recurrent novae, rare WZ Sge Cataclysmic Variables, blazars, X-Ray binaries, and supernovae in the Virgo Supercluster. We report here the discovery of previously unidentified stellar-like objects that underwent abnormally large (?m=5-9) outbursts discovered with DASCH. We also report the discovery of outbursts from previously quiet AM CVn stars, as well as attempt to characterize their recurrence rates.

154.02 – Mining the Stony Brook/SMARTS Atlas of (mostly) Southern Novae: Photometric Studies of Dust Formation in Novae

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The Stony Brook/SMARTS Atlas of (mostly) Southern Novae contains broadband B through K photometry of over 70 novae. More than half of these have sufficient photometric coverage during their first few months that we can investigate the statistics of dust formation. Photometry in the optical alone is sensitive only to dust which forms on the line of sight; near-IR photometry is also sensitive to warm dust in other locations. None of 9 He-N novae were observed to have near-IR excesses interpretable as thermal dust emission, while 80% of classical novae do have excesses at JHK attributable to thermal dust emission. Only 40% of these show evidence for dust dips in the optical, suggesting the dust formation is non-spherical. We shall discuss thermal dust temperatures, masses, formation timescales, and the correlations of dust with optical spectra and nova types.

154.03 – The Search for Cataclysmic Variables using Pan-STARRS1

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Cataclysmic variables are prime examples of extreme celestial phenomena and are also progenitors of Type Ia supernovae. We are working on a pilot study to identify cataclysmic variables (CVs) through Pan-STARRS1 data. For this, we searched for variability using PS1 data for objects in the IPHAS Hα-emitter catalog (such emission being a signature of CVs). This has produced several candidates by identifying features in their lightcurves similar to those for known CVs in PS1 data. We are undertaking follow-up observations of a number of candidate CVs. As PS1 is the first of a new generation of wide-field time domain surveys, this work serves as a pathfinder for the study of outbursting variables using Skymapper and eventually LSST.

154.04 – The Search for Cataclysmic Variables in Dense Globular Clusters

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Cataclysmic variables are rare binary systems composed of an interacting white dwarf and partner star. Symbiotic binaries are rare cataclysmic variables with a red giant as a partner star. Only a single candidate ever found in a globular cluster. Dwarf novae are the periodic outbursts of these variables, and are not well-understood phenomena. Performing photometry of Hubble Space Telescope images over multiple epochs and filters and careful statistical analysis, we scoured the globular clusters NGC 6752 and M15 (NGC 7078) for symbiotic binaries. We located no cataclysmic variables of any sort in NGC 6752, and located six non-symbiotic cataclysmic variable candidates in M15. We then searched for dwarf novae outbursts in the clusters, and located one candidate in M15 outbursting over October 2011.

154.05 – Nova Delphini 2013: Backyard Analysis of a Classical Nova

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On August 14, 2013, Nova Delphini was discovered by Koichi Itagaki. This nova erupted to a maximum brightness of magnitude 4.4 by August 16, 2013. The extraordinary brightness of this event has allowed many amateur astronomers to have the chance to study it. More than 750 amateur astronomers have contributed to the AAVSO photometry database of Nova Delphini.[1] The amount and quality of spectroscopic data gathered is unprecedented as well, as over 700 individual spectra have been collected so far in the ARAS database.[2] A nova is a class of variable star that undergoes a cataclysmic eruption, which can be observed through a sudden increase in brightness that declines over a series of months or years. At the center of a nova is an accreting white dwarf star which is collecting hydrogen from its surroundings. The accreting mass causes a nuclear reaction on the surface of the white dwarf and as the pressure increases the reaction becomes super-critical and a thermonuclear runaway is ignited causing the brightness increase as well as triggering the ejection of a shell of material form the star. The stages of a classical nova outburst are outlined along with techniques available to amateur astronomers for study of these phenomena. The author's equipment and software setup are detailed. Results obtained using a low resolution grating, Schmidt-cassegrain telescope and CCD camera that were acquired while Nova Delphini was in the "fireball stage" [3] and subsequent "iron curtain phase"[3] are compared and discussed. Results obtained using a high resolution spectroscope, Schmidt-cassegrain telescope and CCD camera that were acquired during the "lifting of the iron curtain phase"[3] are also presented. References 1. Turner, Rebecca. "AAVSO – Nova Del 2013" 20 Aug 2013 Web. 8 Sep 2013 <http://www.aavso.org/nova-del-2013> 2. Tessier, Francois. "ARAS Spectral Database – Nova-Del-2013" 22 Sep 2013 Web. 22 Sep 2013 <http://www.astrosurf.com/aras/Aras_DataBase/Novae/Nova-Del-2013.htm> 3. Shore, Steven N. "Spectroscopy of Novae – A User's Manual" arXiv:1211.3176 [astro-ph.SR] 14 Nov 2012

154.06 – Development of the Hα profile in Nova Del 2013

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We report observations of the Hα profile of Nova Del 2013, with resolving power R = 3000. Starting in late August the expected P Cygni profile (blueshifted absorption) was observed. Beginning in September a redshifted absorption appears and strengthens through the month. We will report observations through fall and discuss possible causes of these features.

154.07 – The Old Nova V603 Aquila: A Far Ultraviolet Synthetic Spectral Analysis using its New Hubble FGS Parallax

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1. Villanova Univ., Villanova, PA, United States.

We present the results of a synthetic spectral analysis of the far ultraviolet archival HST and FUSE observations of the fast old nova V630 Aql (P_orb= 3.317 h). Our analysis utilizes the new Hubble FGS parallax distance of 249 pc +9/-8 pc (Harrison et al.2013, ApJ, 767, 7) for this nearly face-on old nova (i = 13 degrees), a white dwarf mass of 1.2 ± 0.2 solar masses (Arenas et al.2000, MNRAS, 311, 135) and a low reddening of E(B-V) = 0.07 (Gallagher & Holm 1974, ApJ, 189, L123). Our analysis includes full, optically accretion disks since V603 Aql is neither a polar nor an intermediate polar (Mukai & Orio 2005, ApJ, 622, 602). We present the results of our FUV spectral analysis and compare them with parameters derived from X-ray studies. This work is supported by NASA grant NNX13AF12G to Villanova University

154.08 – Modeling the Light Curve of the Classical Nova v723 Cas

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On August 24th 1995, the classical nova v723 Cassiopeia (v723 Cas) experienced a sudden thermonuclear outburst, a process by which hydrogen-rich material is accreted onto the surface of a white dwarf and ignited. Observations of the binary system from the last decade suggest that v723 Cas is still emitting in the X-rays as a Super-Soft-Source (SSS). Consequently, it has been hypothesized that v723 Cas has evolved into a permanent SSS and thus has begun its approach to the Chandrasekhar limit. For this reason v723 Cas has been closely followed since its original eruption. Here we present photometric data over a span of seven years (2006 through 2013) taken with the 31" telescope at the National Undergraduate Research Observatory (NURO) in Flagstaff, Arizona. A photometric analysis of the data produced light curves in the optical bands. Modeling of the binary system was also performed using the eclipsing binary star simulator Nightfall for comparison with observations. The data analyzed here reveal an asymmetric light curve, the overall structure of which exhibits a subtle variation in magnitude from year to year.

154.09 – Identification of Recurrent Novae in M31

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Over roughly the past century a total of more than 900 optical transient events have been recorded in M31, the vast majority of which are believed to represent eruptions of classical novae. The impressive dataset of nova positions put together by Pietsch (http://www.mpe.mpg.de/~m31novae/opt/m31/) provides the opportunity to search for multiple nova outbursts from the same progenitor system, and thus to characterize the population of recurrent novae (RNe) in M31. In order to identify RNe candidates, we have searched for spatial near coincidences among the 945 recorded novae given in the Pietsch catalog through the end of August 2013. Given that the positions of many of the early novae are quite uncertain, we have set our initial screen to include nova pairs with nominal separations less than or equal to 6 arcsec. We have identified a total of 102 novae that pass this coarse screen. Of these, 78 novae form 39 pairs, 15 form five triples, four novae are part of a quad, and five novae form a quint. As demonstrated by Shafter, Rice and Daub (2009, presented at the "Wild Stars in the Old West II" conference, mintaka.sdsu.edu/faculty/shafter/extragalactic_novae/RNePoster4.pdf), the majority of the 102 novae surviving our initial screen are expected to be associated with chance positional near coincidences (especially near the nucleus), and are not RNe. To decide which candidates are indeed RNe, we have undertaken a study to locate the original discovery plates, CCD images or published finding charts, and to perform the necessary astrometry to identify which of our candidate RNe are chance positional coincidences, and which are RNe. For each candidate, we estimate the probability that the object is a chance positional coincidence as in Shafter et al. (2009). To date, we have been successful in identifying finding charts or original images for most of the candidates, and have found a total of 23 nova outbursts in M31 associated with 10 systems that are almost certainly RNe.

154.10 – Identifying and Quantifying Recurrent Novae Masquerading as Classical Novae

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Recurrent novae (RNe) are cataclysmic variables with two or more nova eruptions within a century. Classical novae (CNe) are similar systems with only one such eruption. Many of the so-called 'CNe' are actually RNe for which only one eruption has been discovered. Since RNe are candidate Type Ia supernova progenitors, it is important to know whether there are enough in our galaxy to provide the supernova rate, and therefore to know how many RNe are masquerading as CNe. To quantify this, we collected all available information on the light curves and spectra of a time-limited sample of 237 Galactic CNe and the 10 known RNe, as well as exhaustive discovery efficiency records. We recognize RNe as having (a) FWHM of Hα > 2000 km s^1, (b) high excitation lines such as Fe X or He II near peak, (c) eruption light curves with a plateau, (d) infrared colors of J H > 0.7 mag and H K > 0.1 mag, (e) orbital period >0.6 days, (f) outburst amplitude smaller than 14.5 4.5×log(t$_3$), and (g) white dwarf mass greater than 1.2M™. Using these criteria, we identify V1721 Aql, DE Cir, CP Cru, KT Eri, V838 Her, V2672 Oph, V4160 Sgr, V4643 Sgr, V4739 Sgr, and V477 Sct as strong RN candidates. We evaluate the RN fraction amongst the known CNe using three methods to get 24%±4%, 12%±3%, and 35%. With roughly a quarter of the 394 known novae actually being RNe, there should be approximately a hundred such systems masquerading as CNe.

154.11 – Evidence for non-thermal radio emission from a classical nova - V1723 Aql

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The outburst of classical nova V1723 Aql was observed on September 11, 2012. The long term radio observations so far show that it exhibits double-bump radio light curves and partially optically thin spectra. The first bump doesn't follow the classical Hubble Flow Mode which depicts the evolution of thick spherically expanding thermal ejecta. The brightness temperature varies with time and frequencies(1e7 K at 1.38 GHz, 1e5 K at 36.53 GHz, around the first maximum). We examine whether the first bump can be explained by the model of a shock-heated thin shell lying above the main ejecta. The modified model

with linear temperature gradient (T~ r^q, q=0,+/-1) and steep density profile (? ~ r^{-p},p=2,9) in the shell fails to explain the first bump light curves and flat spectra. The late-time observation (~ day 800) implies a spectrum of f? ~ ?^{-0.65} (40 GHz>?>10 GHz) which strongly indicates the existance of non-thermal (synchrotron) emission.

154.12 – Optical Observations of the Cataclysmic Variable FL Ceti, Evidence for a Decrease in Orbital Period

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FL Ceti is a short period cataclysmic variable star belonging to the highly magnetic subclass of polars. Our one second time resolution light curves show dramatic eclipses, as well as a well defined ingress and egress features. We collected 35 hours of broad band optical photometry on FL Ceti at the 82" reflector in the McDonald Observatory. We observed 23 eclipses of the system in 2011. Combining timings of these eclipses with previously publish data we obtain preliminary evidence which indicate that the orbital period of the system is decreasing. We discuss the implications for the derived period derivative and mass transfer rate. This research is supported in part by NSF grant 0958783.

154.13 – The High and Low Accretion States of the Eclipsing Polar LSQ 1725-64

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Magnetic Cataclysmic Variables, also called polars, are known to undergo substantial changes in their optical brightness. These large-scale variations result from changes in the mass transfer rate and are referred to as high and low states. Studying the timescales and observational differences of these state changes constrains their underlying physical causes. LSQ 1725-64 is an eclipsing polar first discovered in a high accretion state by Rabinowitz et al. (2011). We recently found LSQ 1725-64 in a low state, where the accretion is nearly undetectable. Over one week we observed the mass transfer turning back on, returning the system to a high accretion state. For the next 21 days, LSQ 1725-64 was in an enhanced high state, and then returned to the previously observed high state. We collected photometry and spectroscopy with the SOAR telescope, PROMPT, and SALT during all three states, allowing for a study of the changing physical parameters in the system. Differencing the high and low state spectra reveals time-resolved spectra of the accretion stream. Doppler tomography of the stream allows for a geometrical reconstruction of the stream path from the inner Lagrangian point onto the white dwarf hot spot. Doppler tomography of the multiple states elucidates the physical changes occurring in this system as the mass transfer rate changes. This detection of multiple accretion states unambiguously classifies LSQ 1725-64 as a polar and allows for testing of current polar models. These results provide insight into timescales and physical changes happening as polars undergo state changes.

154.14 – Near-Infrared Photometry of Low Accretion Rate Polars

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Low accretion rate polars (LARPs) are thought to be the progenitors of magnetic Cataclysmic Variables (CVs). Polars are highly magnetic white dwarf and a low mass dwarf in a semi-detached configuration. LARPs show little indication of accretion on to the white dwarf, which is how they are identified from other polars. By viewing these systems in the infrared we can identify and model the properties of the low mass red dwarf. We analyzed the photometry obtained with SOAR telescope with OSIRIS with the aid of a light curve modeling tools to estimate the Roche lobe filling factor of this star. Our results enable us to constrain the mass accretion mechanism and give the evolutionary state of these systems.

154.15 – Optical Photometry of BY Cam Modeled Using a Multipolar Magnetic Field Structure

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We present new high-speed broad-band optical photometry of the asynchronous polar (magnetic cataclysmic variable) BY Cam. Observations were obtained at the 2.1-m Otto Struve Telescope of McDonald observatory with 3s integration times. In an attempt to understand the complex changes in accretion flow geometry, we performed full 3D MHD simulations assuming a variety of white dwarf magnetic field structures including both aligned and non-aligned dipole plus quadrupole field

components. We compare model predictions with photometry and various phases of the beat cycle and find that synthetic light curves derived from a multipolar field structure are consistent with the optical photometry.

154.16 – The Second Eclipsing AM CVn Star

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Contributing teams: Palomar Transient Factory Collaboration

We report on PTF1 J191905.19+481506.2, a newly discovered, partially eclipsing, outbursting AM CVn system found in the Palomar Transient Factory synoptic survey. This is only the second known eclipsing AM CVn system. We use high-speed photometric observations and phase-resolved spectroscopy to establish an orbital period of 22.4559(3) min. We also present a long-term light curve and report on the normal and super-outbursts regularly seen in this system, including a super-outburst recurrence time of 36.8(4) d. We use the presence of the eclipse to place upper and lower limits on the inclination of the system, discuss the number of known eclipsing AM CVn systems versus what would be expected, and consider the implications of the weak hot spot identified in phase-resolved spectroscopy.

154.17 – Sakurai's Object Evolving to Higher Temperature

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Sakurai's Object, the prototype final flash object discovered in the mid-1990s, underwent rapid cooling during the first decade of the 21st century, becoming as faint as 25th magnitude at K. This stage of evolution has ceased. Between 2010 September and 2013 April Sakurai's object brightened more than 2 magnitudes in K, to 14.2 in 2013 April. The effective temperature increased to nearly 600 K. The central star remains invisible. AO images show ejected debris with bipolar structure. Near-simultaneous 0.85 - 2.5 micron spectra reveal He I 1.0830 and 2.0587 micron, [C I] 0.9826 and 0.9852 micron, and [N I] 1.0398 micron emission lines. The He I 1.0830 micron emission is spatially extended.

154.18 – Using Light Echoes to Map the Three-Dimensional Dust Structures Around V838 Monocerotis

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The outburst of the unusual transient V838 Monocerotis in 2002 illuminated surrounding interstellar dust, producing the most spectacular light echoes in astronomical history. The echoes remained visible for several years. Because of the light-echo geometry, each imaging observation corresponds uniquely to a well-defined paraboloidal region of space illuminated by the outburst. It is therefore possible to reconstruct the true three-dimensional (3D) distribution of dust around V838 Mon from a series of observations of its light echoes. We obtained images of the echoes using the Hubble Space Telescope (HST) from 2002 to 2011, as well as complementary ground-based data, in order to monitor the evolution of the light echoes at regular time intervals. Based on these images, we reconstruct and visualize the 3D dust density distribution around V838 Mon. Such mapping of the structure helps determine whether the illuminated material represents an outflow from the progenitor of V838 Mon, or pre-existing interstellar dust. A subset of the HST observations, acquired with a high temporal cadence, paves the way to a detailed study of a slab of the dust cloud around V838 Mon on spatial scales as small as ~0.0015 pc or ~310 AU.

154.19 – Imaging Polarimetry of the Yellow Hypergiant IRC+10420 at 2.2 μm with MMTPOL

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We present imaging polarimetry of the circumstellar environment of the yellow hypergiant star IRC +10420 obtained as part of first light observations with MMTPOL, the 1 - 5 μm imaging polarimeter commissioned in Fall 2012 at the 6.5 m MMT telescope on Mount Hopkins, AZ. Achieving an angular resolution at λ = K (2.2 μm) of 0.2? (near the diffraction limit despite windy non-photometric conditions), MMTPOL has resolved polarized emission from IRC +10420's circumstellar nebula to within ~ 0.5? of the bright central star. The polarization position angles exhibit a clear circosymmetric pattern consistent with scattering from dust grains formed during a period of sustained mass loss. We map fractional polarizations from ~ 5% to 50% for radii between 0.5? to 3.0? from the star (2,500 to 15,000 AU at 5 kpc), with the highest polarization found at a radius of 1.6?. Assuming scattering from astronomical silicate grains with average radius ~ 0.3 μm (a typical size as found recently for the hypergiant star VY CMa), this high polarization is consistent with scattering angles of either ~ 60° and/or ~ 120°. This places the grains at ~ 30° in front of the plane of the sky or behind it, respectively.

154.20 – A Far Ultraviolet Spectroscopic Analysis of the Hot Components in Six S-Type Symbiotic Variables

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We have carried out a far ultraviolet spectroscopic analysis of archival IUE and HST spectra of six symbiotic variables. Two systems, LT Del, which has had one recorded outburst, and BD-21 3873 (= IV Vir) which has had no recorded outburst, are yellow symbiotic systems. Two systems, V443 Her and RW Hya, have also never had a recorded outburst. Two other symbiotics, StHα190 and CQ Dra, are more strongly interacting with an outburst history. We have studied these systems during their quiescence in order to shed light on the nature of their hot components by fitting the observations with optically thick accretion disk models and model white dwarf photospheres. We present the results from our synthetic spectral analysis. This research was supported by NASA grant NNX13AF12G

154.21 – FUV, UV, and Optical Observations of the He-sdO Star BD+39 3226

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Based on observations carried out with the Far Ultraviolet Spectroscopic Explorer, the Space Telescope Imaging Spectrograph, the MMT Observatory, and the Keck telescope HIRES spectrograph, we present a spectral analysis of the He-sdO star BD+39 3226. By fitting the MMT spectrum we obtain a gravity that is 0.7 dex higher than the one reported in the literature. The new atmospheric parameters will have an impact on the measurement of the HI column density toward BD+39 3226, and by this very fact on the deuterium abundance. The high-resolution spectra show stellar absorption lines coming from C, N, O, Si, P, S, Fe, and Ni. The spectra also show lines from heavy elements such as Ge, As, and Sn. On the other hand, neither Zr nor Pb absorption lines are detected. The non-detection of lead in BD+39 3226 indicates that the star does not belong to the newly discovered group of lead-rich He-sdO stars. P.C. is supported by the Canadian Space Agency under a Public Works and Government Services of Canada contract.

154.22 – Does Episodic Mass Loss Dominate the Evolution of Massive Stars?

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Evolution of the most massive stars such as ? Carinae is controlled by the effects of mass-loss, possibly dominated by poorly understood stellar eruptions and episodic mass ejections. Copious mass loss leads to circumstellar dust formation, obscuring the star in the optical. But as the light is absorbed and re-emitted by the dust, these objects become very luminous in mid-infrared light. Understanding these stars is challenging because no true analogs of ? Car have been found so far in our or other galaxies. We present the results of our systematic search for ? Car analogs in 7 galaxies utilizing data from Spitzer, Herschel, HST and other sources. While strict ? Car analogs remain to be found, if they exist, we discovered a new class of luminous, heavily dust obscured, massive stars. We describe the properties of these stars and discuss the implications of our findings for massive star evolution and their resulting supernovae.

154.23 – The Role of the Magnetorotational Instability in the Late Stages of Stellar Evolution

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The magnetorotational instability (MRI) has proven to be a key piece of physics in accretion disks and is widely considered to play some role in core collapse, but its role in stellar evolution has been substantially neglected. This is in part because a threshold shear is required to trigger the MRI and the MRI tends to be stabilized by strong composition gradients. Models of rotating massive stars naturally develop very strong shear at composition boundaries, and the MRI is subject to triply-diffusive destabilizing effects in radiative regions. The MRI grows exponentially rapidly when unstable and can be active in convective regions. We have used the MESA stellar evolution code to compute rotating stellar models with magnetic effects due to the Spruit-Taylor mechanism and the MRI, separately and together, in a sample of massive stars. We find that the MRI can be active in the late stages of massive star evolution, slowing core rotation and leading to mixing effects that are not captured in models that neglect the MRI.

154.24 – Polarization of circumstellar bow shocks due to electron scattering

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Circumstellar material (CSM) provides a link between interacting supernovae and their massive progenitor stars. This CSM arises from stellar winds, outflows, or eruptions from a massive star before it explodes and can be detected around stars or supernovae with polarimetric observations. We use a Monte Carlo based radiative transfer code (SLIP) to investigate the polarization created by different models for the CSM surrounding a central source such as supernovae or massive stars. We vary parameters such as the shape, optical depth, temperature, and brightness of the CSM and compare the simulated flux and polarization behavior with observational data. We present results from new simulations that assume a bow shock shape for the CSM. Bow shocks are commonly observed around massive stars; this shape forms when a star moving more quickly than the speed of sound in the local interstellar medium emits a stellar wind that drives a shock wave into the ISM. Since a bow shock projects an aspherical shape onto the sky, light from the central source that scatters in the shock region becomes polarized. We present electron-scattering polarization maps for this geometry and discuss the behavior of observed polarization with viewing angle in the unresolved case.

154.25 – The Morphology and Uniformity of Circumstellar OH and H2O Maser Shells Surrounding OH/IR Stars

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Stars that are classified as OH/IR stars can be used to study key parts of the late evolutionary sequence of stars. These parts include stellar mass loss and planetary nebulae formation. These stars are named OH/IR stars because of the high detection of infrared (IR) emission and the detection of the OH masers found in the nearby regions of these stars. They are interesting stars because they are not observable in the optical. This property stems from the fact that optical light is blocked by a circumstellar shell of material that has formed around the star through stellar mass loss. From studying these objects with radio and IR observations we can obtain information on the star's size, locations and thickness of dense portions of the circumstellar shells, molecular composition, regional temperatures, density of particles, velocity of expanding shells, uniformity of the shells, and magnetic field strengths. We undertake studying these stars at high resolutions with both radio and IR observation to be able to extract more detail that can improve the current mass loss models for these stars.

154.26 – VISION: Next Generation Beam Combiner for the Navy Precision Optical Interferometer

Eugenio Garcia[1,2], Gerard van Belle[2], Matthew W. Muterspaugh[3], Samuel Swihart[4]
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The Visible Imaging System for Interferometric Observations at NPOI (VISION) is a versatile beam combiner for the Navy Precision Optical Interferometer (NPOI). VISION is a fiber-optics based beam combiner that can coherently combine light from up to 6 telescopes simultaneously using an image-plane combination scheme. VISION was inspired by the Michigan Infrared Combiner (MIRC) for the CHARA array – but VISION operates at optical wavelengths. With planned resolutions of

<0.2 milli-arcseconds, VISION will be used to reconstruct multi-pixel time-varying images of evolved (luminosity class I-III) stars – in other words, movies of stellar surface variations. VISION's visible light beam combination will be able to uniquely characterize surface features of stars less accessible at infrared wavelengths by interferometers such as CHARA. The "classic" beam combiner for NPOI employs a pupil–plane image combination which has visibility amplitude and closure phase precisions of 5-20% and 1-10 degrees respectively.VISION features a photometric camera for calibrations, spatial filtering from single mode fibers, and negligible read noise with a modern Andor Ixon CCD. These features will enable a factor of 10 improvement in visibility amplitude and closure phase precisions.

154.27 – 110-day Spectral Record of the Classical Nova Delphini 2013

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The August 14, 2013 eruption of Nova Delphini 2013 presented a unique opportunity for amateur astronomers to study the evolution of a classical nova. We present a 110-day spectral record of the evolution of this nova acquired with a low-resolution 100 line per millimeter grating and a commercially available CCD camera mounted on an 14" Schmidt Cassegrain telescope. Records were acquired beginning one day after discovery. At the time of writing this abstract 44 spectra over 110 days have been acquired and analyzed. Raw data were calibrated against star 29vul a type A0V with clear H-Balmer lines. Spectra were then corrected for instrument response and analyzed with commercially available software from Field Tested Systems (R-Spec ®). Earliest spectra highlight characterizes of the fireball phase with a bright continuum and clear H-Balmer emission lines. The transition to the Iron Curtain phase is uncertain in our spectra because of lack of sensitivity in the UV. By +6 days the expanding gas shell has cooled to the point where various emission lines appear prominently; particularly H-α, Hβ , and Fe II. Elemental oxygen (O I) at 7773 and 8446 Å also emerges from the continuum and by +10 day dominate the near-IR. Further progression shows the C III and N III complex at 4640 Å and He I at 7065 Å. Further evolution of the phases of Nova Delphini 2013 is clearly defined in the emission spectra. Lyman-β pumping of O I at 8446 Å is clearly evident by +17 days and drops precipitously between days 48 and 49. The nebular phase becomes apparent when O III at 5007 Å becomes obvious.

154.28 – The Radio-Emitting Ejecta from Classical Nova V1723 Aql

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In the optical, V1723 Aql appears to be a typical fast classical nova of the Fe II spectral type; in the radio, however, it reveals itself to be something far more complex. Since its discovery in 2010 September, we have been monitoring V1723 Aql with the Karl G. Jansky Very Large Array (VLA) at multiple frequencies between 1 and 37 GHz, producing one of the most complete, long-term set of multi-wavelength radio observations for any classical nova to date. Although late time radio emission is consistent with an expanding spherical shell emitting thermal bremsstrahlung emission, the earliest observations revealed an additional source of strong, transient radio emission, suggesting the presence of shocks. The development of the radio spectra suggests that the shell was formed from impulsive ejection(s) rather than a finite duration wind; the spectra allow for preliminary measurements of the inner boundary of the expanding shell, and provide an estimate of the mass of the ejected material on the order of 10^{-4} M™. These observations have implications for understanding the role of shocks in producing excess radio emission as well as high energy emission in novae.

155 – Binary Stellar Systems, X-ray Binaries
Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

155.01 – The Cygnus OB2 Radial Velocity Survey: Solutions of Four More Systems

Jamie Burke[2, 1], Henry A. Kobulnicky[1], Daniel A. Dale[1], Emily Rolen[3, 1], Katie V. Lester[4, 1], Erica Keller[5, 1], James E. Chapman[6, 1], Eric Topel[7, 1]
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Over the summer of 2013, six undergraduate students from around the country, including myself, participated in an REU at the University of Wyoming, where we contributed to the orbital solutions of 22 binary systems in the Cyg OB2 Association. This is part of the larger Cygnus OB2 Radial Velocity Survey, which has been conducted intermittently by Henry Kobulnicky, the project head, for the past fourteen years. So far it has uncovered 47 binary systems out of the 143 known massive star systems in the association, and is the most complete survey of a massive star association yet done. Radial velocity measurements were done over the summer on the He 5876 line using a spectrograph at the 2.3 m telescope at WIRO, the Wyoming InfraRed Observatory. The four systems I solved, MT202, MT295, MT455, and MT555, are all low-amplitude, with MT202 having the highest velocity semi-amplitude of 21 km/s, and the others having semi-amplitudes under 10 km/s. Three of the systems are short-period, with periods of 2.60077, 2.0900, and 4.1797 days for MT202, 295, and 455 respectively, while MT555 has a much longer period of 279.467 days. MT202 and MT295 are both B2V stars, and MT455 and MT555 are O8V stars. There is difficulty in constraining the masses and spectral types of the secondary stars due to the lack of information about the inclination of the systems, so lower limits for the masses of the secondaries are typically around 0.5 solar masses, whereas upper limits for the mass are the masses of the primaries. This work is supported by the National Science Foundation under REU grant AST 1063146.

155.02 – Massive OB Binary Star Characterization in the Cygnus OB2 Association

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We present the orbital parameters of three new massive binary stars inthe Cygnus OB2 Association, the largest nearby (1.4 kpc) collection of massive stars. Using spectroscopic data obtained at the Wyoming Infrared Observatory between 2010 and 2013 we determined the orbital parameters of the three stars showing velocity variability: MT448, MT187, and MT299. MT448 (insert spectral type) has the least eccentric orbit (e=0.10) with a velocity amplitude of K1=28 km/s and a period of P=3.17 days. MT299 has a more eccentric orbit (e=0.43) with a velocity amplitude of K1=7 km/s and an orbital period P=41.5 days. MT187 has the smallest velocity semi-amplitude with K1=4 km/s and periodP=13.5 d. These add to the growing number of known massive binaries inCyg OB2, with nearly 50 systems having complete orbital solutions. This work is supported by the National Science Foundation under REU grant AST 1063146.

155.03 – The Cygnus OB2 Radial Velocity Survey: Discovery of three new single-lined massive binary systems

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In a continuation of the Cygnus OB2 Radial Velocity Survey, we have obtained spectra with the Wyoming Infrared Observatory (WIRO) 2.3 m telescope and longslit spectrograph from 2010-2013. Data from Keck and WIYN observatories from 1999-2008 are also used. MT483 (O5I primary) is a low amplitude system just within our range of detection with a period of 4 days and a velocity amplitude of 24.2 km/s. MT473 (O8.5V primary) is most likely double-lined and the system is

composed of at least 3 stars. Two of these stars are most likely in a tight binary with a period of P=3.6 days. An unseen companion, which must be at least a B star, appears to have a period of 1687 days. MT241 (B2V primary) is a long period system that needs more data, but has a preliminary period of 728 days with a velocity amplitude of 15.3 km/s. We also show data for MT480 and MT005, systems that showed small random variations that are not indicative of orbital motion. This work is supported by the National Science Foundation under REU grant AST 1063146.

155.04 – The Cygnus OB2 Radial Velocity Survey: Three new massive binaries MT216, MT234, MT485

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We report continued results from the Cygnus OB2 Radial Velocity Survey in search of massive binary stars. Using the Wyoming Infrared Observatory's 2.3 m telescope and long slit spectrograph, we obtained spectra of early type stars during the summer of 2013, to which we added spectra taken over the last few years. By calculating the Doppler shift of the Helium λ5876Å absorption line, we calculated the radial velocity variations and solved for the orbital solutions for each star. We find that MT216 (B1.5 V, K=7.67 km/s), MT234 (B2 V, K=16.4 km/s), and MT485 (O8 V, K=11.9 km/s) are single-lined spectroscopic binaries with periods of 37 days, 13.96 years, and 12.44 years, respectively. MT556 (B1 I) exhibits irregular variations characteristic of atmospheric rather than orbital fluctuations. This work is supported by the National Science Foundation under REU grant AST 1063146.

155.05 – The Cygnus OB2 Radial Velocity Survey: A Study of Six Additional Massive Systems

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We used the Wyoming Infrared Observatory's 2.3 m telescope and longslit spectrograph to monitor six suspected binary stars as part of the Cygnus OB2 Radial Velocity Survey during the summer of 2013. We determined the orbital parameters of probable binaries based on radial velocity measurements of the He I 5876 lines. Of the six stars surveyed, four are clearly binary. MT021 has an orbital period of 9.716±0.004 days and a velocity semi-amplitude of 37.5±2.5 km/s. MT292 has an orbital period of 14.80±0.001 days with a velocity semi-amplitude of 25.32±2.69 km/s. MT339 has an orbital period of 44.63±0.03 days with an eccentricity of 0.57±0.07 and a velocity semi-amplitude of 4.2±0.8 km/s. MT561 shows an orbital period of 40.090±0.030 days and a velocity semi-amplitude of 35.2±3.6 km/s. MT692 shows no detectable radial velocity variations and appears to be single. MT215 exhibits some velocity variation but no definitive periodicity is yet available. These confirmed binary systems contribute to the increasingly complete sample of massive binaries in Cygnus OB2, now numbering nearly fifty. This work is supported by the National Science Foundation under REU grant AST 1063146.

155.06 – The Cygnus OB2 Radial Velocity Survey: MT378, MT601, MT268, and MT646

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The Cygnus OB2 Radial Velocity Survey is an ongoing effort to identify and characterize massive spectroscopic binaries in the CygOB2 association using data obtained at the Wyoming Infrared Observatory's 2.3 meter telescope. This association, the

largest nearby collection of massive starts, is located only 1.4 kiloparsecs from Earth. This poster presents four new single-lined binaries in the region: MT378 (a B0V star with an orbital period of 32 days), MT601 (O9.5III/404 days), MT268 (B2.5V/71 days), and MT646 (B1.5V/11 days). The data produced by this survey should prove useful in determining the role of close companions in the formation, evolution, and eventual demise of massive stars.

155.07 – Radial Velocity Monitoring of Composite-Spectra Hot Subdwarf Stars with the HET

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The enigmatic hot subdwarf B (sdB) stars represent one of the least-understood stages of stellar evolution. Theory shows that they likely formed from red giant branch stars that lost their outer envelopes due to Roche lobe overflow and common envelope interactions with a companion. Binary population synthesis models are generally successful at reproducing the observed orbital periods of sdB binaries with M dwarf and white dwarf companions; the story for sdB+F/G/K binaries, however, is still being written. Relatively few observational constraints have been published for these composite-spectra systems. We have been monitoring the radial velocities (RVs) of 15 sdB binaries with F-K dwarf companions since 2005 using the Medium and High Resolution Spectrographs on the Hobby-Eberly Telescope. Here we present RV measurements and orbital parameter estimates for selected systems in our sample. We also present an up-to-date orbital period histogram for all known sdB binaries, including both short- and long-period systems. Our results suggest that those with F-K main sequence companions have periods on the order of 1.5 to 3 years. Several of the long-period binaries show strong evidence for non-circular orbits, challenging the conventional Roche Lobe overflow formation channel for hot subdwarf stars. This material is based upon work supported by the National Science Foundation under Grant No. AST-0908642.

155.08 – Exploring Binary Populations in Open Clusters

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We present properties of binary populations in several key open clusters. Combining optical UBVRI data with near-IR JHK_S and mid-IR [3.6][4.5][5.8][8.0] photometry, we are able to identify binaries photometrically in open clusters over a wide range of masses, particularly for faint lower main sequence stars. This method will also allow for accurate determination of stellar masses and binary mass fractions. Using these results, we will explore mass segregation of both singles and binaries, binary fraction as a function of primary mass, and mass ratio distribution as a function of primary mass, all as a function of age from 350 Myr to 9 Gyr. Using this information, we can compare to current prescriptions used in cluster N-body simulations.

155.09 – Period Discovery and Light Curve Analysis of the Young 25 Ori Association Eclipsing Binary GSC 118-199

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GSC 118-199 (5-6432) was discovered to be an eclipsing binary by Van Eyken et al. (2011) in their intensive monitoring of the young (7-25 Myr) 25 Ori association as part of the Palomar Transient Factory (PTF) Orion project. However, because of the brightness of the system (Rc = 12.7 mag), their instruments could only accurately monitor the binary during its deep (0.6 mag in Rc) total eclipse. They did not observe enough eclipses to reliably determine a period and no secondary eclipse was ever detected. GSC 118-199 was observed at Eastern University from Feb 2011 – Mar 2013 in order to discover the period and subsequently analyze the light curve of this presumably very young totally eclipsing system. More than 3500 observations in V and Rc were obtained and several primary and secondary eclipses were secured and an accurate period determined. The secondary eclipse depth was measured to be ~0.1 mag in Rc centered at 0.496P in phase. The ephemeris for the system has been determined to be 2455189.72682(5) + 6.185181(4) E. Preliminary light curve analyses indicate that the system is a detached, totally eclipsing binary, where the larger but less massive component is the cooler star by ~3000 K. The system also exhibits a slightly eccentric (~0.02) orbit, a typical indicator of youth in a binary system. This poster will investigate the possible ramifications of the unusual nature of this young system with the hope that additional observations obtained in late 2013 will provide additional weight and clarity to the preliminary solution.

155.10 – Light Curve Analyses of the Short Period, Totally Eclipsing Binaries V449 & V463 And

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As part of our ongoing research on short period eclipsing binaries which do not have published precision light curves and/or analyses, we placed V449 & V463 And on our observing schedule for the fall of 2013. V449 And (GSC 3281-2158; Mis V1190) was reported by Kazarovet (2005) to be a short period (0.33853 day) overcontact system ranging from V = 12.2 – 12.9 mag. We have obtained more than 1300 total observations in V and Rc. Preliminary light curve analysis reveals a W-type overcontact system with the primary eclipse being total and a temperature difference between the stars of ~300 K. The light curves themselves are fairly symmetrical (not typical for these types of systems) except for a more rapid rise in the ascending branch after secondary eclipse than symmetry would predict. This seems quite peculiar, as most W-UMa light curves exhibit asymmetries primarily between maxima (the O'Connell effect). Detailed modeling including hot and/or cool spots will be presented, as well as a period study based upon the limited timings available. V463 And (GSC 2764-1417; NSV 14514) was discovered by Khruslov and reported in IBVS 5699 (2006) to be a short period (0.406095 day) system ranging from V = 12.15 – 13.05 mag. Our thoroughly covered V and Rc light curves show that the secondary eclipse is total. Subsequent analysis indicates the system is most likely a near-contact binary with a temperature difference of ~1200 K between the components. The light curves also demonstrate very significant asymmetries, especially near secondary eclipse. The O'Connell effect is 0.08 mag in Rc between the two maxima and the first maxima is significantly asymmetrically shaped. Modeling results including spot analysis and a period study will be presented in this poster.

155.11 – SARA South Observations of the W U Ma Pre-Contact Binary, ZZ Eridani and its Near-Brown Dwarf Companion

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We present the first precision BVRI light curves, and synthetic light curve solutions and a period study for the 14th (13.9-15.0) magnitude (V) southern pre-contact W UMa binary, ZZ Eridani. Observations were taken with the Southeastern Association for Research in Astronomy (SARA) South Telescope, a 0.6-m reflector during 15 October through 30 December 2012. The 2MASS photometry indicates that the binary is a ~G5 spectral type. Our light curves were premodeled with Binary Maker 3.0, and simultaneously solved with the Wilson-Devinney program. The observations included 288 B, 298 V, 301 R and 300 I individual and calibrated observations. These were taken with the QSI 683s CCD camera cooled to -25C. Seven mean times of minimum light were determined, including HJDMin I = 2456264.5902±0.0043, and 2456243.7953±0.0011, 2456244.7009±0.0008, 2456248.7695±0.0008, 2456210.7966±0.0002 and HJD Min II = 2456264.8194±0.0027 and 2456216.8928±0.0026. Twenty seven more eclipse timings were taken from the literature for our calculation of its first precision ephemeris. The O-C curve is a low amplitude sinusoid, possibly indicating the presence of a third component. J.D. Hel Min I = 2456264.5863±0.0027d + 0. 45205976±0.00000015×E + 0.0048(±0.0002)×SIN[(0.00023±0.00002)×E+ 2.0±0.4] Using the amplitude from this ephemeris, a binary mass of ~1.5 solar masses, and its mass ratio, and inclination from our Wilson-Devinney program solution, we determined the third body to have ~0.11 solar masses , somewhat above the threshold for a brown dwarf. The light curve has the appearance of an Algol (EA) type, however it is made up of dwarf solar type components in a detached mode with a period of only 0.4521 days. The light curve solution gives a mass ratio of 0.6, an inclination of 85°. The fill-outs are 95.2% and 95.3% for star one (hotter more massive component) and star two, respectively. The model includes one 23 degree diameter cool magnetic spot on the secondary component.

155.12 – V530 Andromedae: A Totally Eclipsing Near-Contact Solar Type Binary

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We present the first precision UBVRcIc light curves, an initial period study, along with a simultaneous light curve solution for the short period, P= 0.577217(3)d near contact solar type eclipsing binary V530 Andromedae. Our observations were taken with the 0.81 m Lowell reflector on 27 and 29 September 2011 with time granted from the National Undergraduate Research Observatory (NURO). The temperatures of the primary and secondary components are estimated at 7000 and 6500 K, respectively. Our Wilson code solution yields a semidetached, V1010 Oph configuration: the more massive component is filling its Roche lobe while the secondary is slightly under filling, at 98.97% of its respective surface. The mass ratio, M2/M1, was found to be 0.3786±0.0003 and two star spots, probably magnetic in origin, were modeled, one on the surface of either star. The system is apparently approaching contact for the first time.

155.13 – Position angle and separation of binary stars selected from the Washington Double Star Catalog

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We report on separation and position angle measurements of binary star systems, selected from the Washington Double Star catalog. This data is acquired at the 31 inch NURO telescope, located 20 miles east of Flagstaff, Arizona. The NASACAM CCD camera, with 27-micron pixels and a field of view of 16 arc minutes is attached to the telescope when collecting the images for this project. . Then, the images are pixelized and finally, the separation and the position angle of the star system are measured. The data is then published at the Journal of Double Star Observations. This research project is part of an ongoing gathering of data that has been active for various years. We include stars with data from various years.

155.14 – Separated Fringe Packet Binary Star Astrometry at the CHARA Array - An Update

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When observed with optical long-baseline interferometers (OLBI), components of a binary star which are sufficiently separated such that their interferometric fringe packets do not overlap are referred to as Separated Fringe Packet (SFP) binaries. At the CHARA Array these `wide' binaries are in the range of a few tens of milliarcseconds and extend out into the regime of systems resolved by speckle interferometry at single, large-aperture telescopes. These SFP measurements can provide additional data for orbits lacking good phase coverage, help constrain elements of already established orbits, and locate new binaries in the under-sampled regime between the bounds of spectroscopic surveys and speckle interferometry. Unlike binary stars whose fringes overlap, a visibility calibration star is not needed, and the separation of the fringe packets can provide an accurate vector separation. We apply the SFP approach to Omega Andromeda, HD 178911, and Xi Cephei. For these systems we determine masses for the two components of 0.963+/-0.049 M_{sun}; and 0.860+/-0.051 M_{sun}; and an orbital parallax of 39.54+/-1.85 mas for Omega Andromeda, for HD 178911 masses of 0.802+/-0.055 M_{sun}; and 0.622+/-0.053 M_{sun}; with orbital parallax of 28.26+/-1.70 mas, and masses of 1.045+/-0.031 M_{sun}; and 0.408+/-0.066 M_{sun}; orbital parallax of 38.10+/-2.81 mas for Xi Cephei.

155.15 – Wide Binaries in the Kepler Field: Using Rotation Periods to Constrain Gyrochronology Models and Planetary Occurrence Rates

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The determination of precise stellar ages is a fundamental step in understanding the formation and evolution of stellar and planetary systems. Using 1547 common proper motion binary pairs in the Kepler field of view, we examine coeval star systems to calibrate gyrochronology models, the empirical relationship between photometric color, stellar rotation period and age, and investigate the influence of stellar age on planetary occurrence rates. Although gyrochronology may ultimately provide a distance-independent method of determining stellar age over all spectral types, previous models have been limited by sample size and biased toward young, nearby star clusters. As rotation periods are most often measured from star spot modulations, the most populous type of stars in the Galaxy (older, less active stars with fewer or no spots) have been largely left unmonitored and the age-rotation relationship untested at older ages. However, due to Kepler's high-precision time series photometry and dense field of view, we can now observe stars with small spot coverage and in multiple-star systems, probing gyrochronology models in an unprecedented regime. While Kepler's field of view includes four open star clusters that we will use as baseline chronometers, binary pairs are the ideal alternative to constrain an effective age-rotation relationship, as they preserve the coeval baseline required for gyrochronology and, unlike clusters, span a wide range of ages. We will also present preliminary results regarding the age-rotation relation's influence on planetary frequency, highlighting binary systems with one or more planet candidates.

155.16 – Masses and Radii of Low-Mass Companions in Short Period Eclipsing Binary Systems Selected from STEREO Data

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As part of our project for studying bright (V < 10 mag) Eclipsing Binaries discovered using images from the NASA STEREO mission we are accumulating follow-up observations with the goal of complete systems characterization. The full complement of data consist of light curves extracted from STEREO photometry, wide coverage Echelle spectra obtained at Apache Point Observatory for stellar characterization and Coude spectra obtained at NAO Rozhen for radial velocity curves. Here we present physical parameters for six short period (p < 3 d) single line binary systems containing low-mass components. Two

methods were used for obtaining the fundamental parameters (masses and radii). The first method assumes the rotation of the primary has been synchronized with the orbital motion of the secondary and aligned with the orbital axis. This assumption in combination with the parameters measured from the light curves, the RV curves, and the Echelle spectra, makes it possible to determine the masses and radii of individual components. The second method relies on modeling the binary systems with the Wilson-Devinney code. Basic parameters measured from the light curves (period, radii ratio) and RV curves (amplitude, eccentricity) are fixed and used to feed the code. This helps to reduce the number of free parameters and to fully utilize the available information. A complete simultaneous solution is obtained that includes orbital elements of the binary systems along with fundamental parameters such as masses and radii of both components. We compare the results from the two approaches and discuss the uncertainties and caveats in each of the two methods.

155.17 – Revealing Imposters: A Target Pixel View of Eclipsing Binary False Positives

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Using the Kepler Eclipsing Binary Catalog, we identify false positives using Kepler Target Pixel level data observed at ~30 minute cadence. Identification of possible false positives was completed by producing a plot of target pixel file data over plotted on the sky with identified KIC objects. A correlation plot was then produced to see how well each pixel correlated to the total light curve. If the correlation was not relatively high throughout the whole Kepler generated mask, and was localized to specific portions of the mask, then this was identified as a potential false positive. Using the light curve of a nearby KIC object and using the same correlation procedure discussed above on the predefined mask, we determine whether or not the total light curve of the identified local KIC correlates to the individual pixels that did not have a high correlation to the original lightcurve. We detrend the fluxes of each target pixel using the keppy python package to get a better idea of where the binary activity is present. These detrended fluxes were used only to visually identify the binary signature. Using the target pixel level data allows us to see if the binary activity is centered on the automatically generated Kepler mask. If the binary is not centered in the generated mask, we create a new custom mask that is centered on the binary. This mask is generated from the original unedited target pixel data. From this new mask, we generate light curves of the actual binary. We have determined that approximately 30% of the identified binaries are false positives which have very large implications on our understanding of the frequency of binaries in the Kepler field.

155.18 – Beyond Binarity: Spots, Pulsations, and Triple Systems

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We use the Kepler Eclipsing Binary Catalog (Prsa et al. 2011) to find and explore previously unstudied intrinsic stellar variability and stellar multiplicity. All but the highest-amplitude intrinsic variation in these systems is dominated by the eclipsing binary signature, however by fitting a physical model to the eclipsing binary signal and then subtracting this model from the lightcurve, we effectively remove binary effects and can search the residuals for other sources of variability. Using 120 stars for our sample, observed at a 1-min cadence by NASA's Kepler satellite (Borucki et al. 2009), we find low amplitude spot variation, pulsations, and background eclipsing binary stars. Frequencies derived from the spot variations and pulsations provide us with information on the rotation rates, internal structure and physical parameters of the stars that comprise each system. Using frequency and period relations derived by Tassoul (1980), we identify g-mode and p-mode pulsations from the derived signals. We apply asteroseismic methods to interpret these signals and determine the radii and masses of the system components, differential surface and interior rotation, and evolutionary state of these stars. Binary star modeling of these systems yields independent values of the masses, radii, and temperatures of both components, as well as any tidal deformation that may occur. By coupling these approaches, we aim able to construct a fully consistent model of the systems that undergo these variations. We highlight systems of particular interest and discuss frequently observed features in the power spectra.

155.19 – Inferred Eccentricity and Period Distributions of Kepler Eclipsing Binaries

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Determining the underlying eccentricity and orbital period distributions from an observed sample of eclipsing binary stars is not a trivial task. Shen and Turner (2008) have shown that the commonly used maximum likelihood estimators are biased to larger eccentricities and they do not describe the underlying distribution correctly; orbital periods suffer from a similar bias. Hogg, Myers and Bovy (2010) proposed a hierarchical probabilistic method for inferring the true eccentricity distribution of exoplanet orbits that uses the likelihood functions for individual star eccentricities. The authors show that proper inference outperforms the simple histogramming of the best-fit eccentricity values. We apply this method to the complete sample of eclipsing binary stars observed by the Kepler mission (Prsa et al. 2011) to derive the unbiased underlying eccentricity and orbital period distributions. These distributions can be used for the studies of multiple star formation, dynamical evolution,

and they can serve as a drop-in replacement to prior, ad-hoc distributions used in the exoplanet field for determining false positive occurrence rates.

155.20 – A Triple Eclipsing System as a Test Case for Close Binary Formation Through Kozai Cycles

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Kozai cycles and tidal friction of a binary with a tertiary companion is one of the leading theories for the formation of close binary systems by tightening the orbit of the inner binary (Kozai 1962; Kiseleva et al. 1998). According to simulations, such systems should evolve into tight inner binaries with eccentric tertiary companions on wide orbits, and importantly predict the tertiary to have an orbital inclination misaligned relative to the plane of the inner binary, with an angle of misalignment that peaks strongly around 40 degrees (Fabrycky & Tremaine 2007). KIC 2835289 is a triple system comprising a ?0.9 day inner binary and a tertiary on a ?750 day orbit. The tertiary was identified through our eclipse timing variations and our finding of a tertiary eclipse event in the Kepler data (Conroy et al. 2013). Here we show, using photodynamical modeling of the system, that the tertiary in this system is on an eccentric orbit inclined ?40 degrees with respect to the inner binary, in superb agreement with theoretical prediction. KIC 2835289 is thus the first known triple system that directly attests to the key predictions of Kozai cycles and tidal friction as a mechanism to tighten binary star systems.

155.21 – Analysis of Refined Parameters of the Eclipsing Hierarchical Triple Stellar System KOI-126

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KOI-126 was the first eclipsing hierarchical triple stellar system identified in the Kepler mission's photometry. The system contains a low-mass binary, KOI-126 B and C, with a period of $P1 = 1.76713 \pm 0.00019$ days, orbiting a third star, KOI-126 A, with a period of $P2 = 33.9214 \pm 0.0013$ days (Carter et al. 2011). The geometry and dynamics of the system are such that determination of the parameters of each of the three stars can be made accurately (better than a few percent) from the photometry alone, although using the radial velocities of star A yields an improvement of roughly a factor of 3-5 in precision. Carter et al. measured the masses of KOI-126 B and C to be 0.2413 ± 0.0030 M™ and 0.2127 ± 0.0026 M™, with radii 0.2543 ± 0.0014 R™, 0.2318 ± 0.0013 R™ respectively. KOI-126 A was measured to have a mass 1.347 ± 0.032 M™ and a radius 2.0254 ± 0.0098 R™ with an eccentricity around the low-mass binary of $e2 = 0.3043 \pm 0.0024$. The original analysis employed a full dynamical-photometric model, utilizing a Levenberg-Marquardt algorithm and least-squares minimization, to fit the short-cadence (i.e. one minute exposures) photometric data from Kepler captured over a period of 247 days. The complete set of short-cadence data now covers a span of ~1,300 days. In light of the new data, and the valuable contribution that accurately measured fully-convective stars can offer to theoretical stellar models, we refined the parameters of this system. This new analysis was done using the same dynamical-photometric model developed by Carter et al. and incorporates a Markov chain Monte Carlo (MCMC) algorithm with least-squares minimization to fit the parameter space. We discuss the implication of our results in the context of evolutionary models for low mass stars. We acknowledge support from the National Science Foundation via the grant AST-1109928.

155.22 – Characterizing the Eclipsing Binary KOI 1120

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Because the NASA Kepler Mission is primarily a search for exoplanetary objects, its exquisite photometric precision has also opened scientific frontiers in stellar astrophysics. As part of the cool Kepler eclipsing binary program, we present a case study of a particularly interesting KOI false positive—KOI-1120. This K giant/G dwarf eclipsing binary pair reveals a deep secondary eclipse of 16% and a 7% primary eclipse depth with multiple star spot crossing events over the Kepler time baseline. Kepler data supplemented with Keck/HIRES radial velocity measurements, Keck/NIRC2 adaptive optics imaging, and Palomar/TripleSpec near infrared spectra enable precise and accurate modeling of the system. Characterizing this distinctive system will provide important insights into stellar astrophysics and stellar evolution.

155.23 – Accurate Parameters of Two Bright Eclipsing Binaries with Potential for Asteroseismology

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In the determination of the dimensions of celestial objects, it is important to confirm results through multiple independent methods. Asteroseismology can be employed to determine the stellar density based on the observed pulsation spectrum of a star for which a high quality light curve is available. This stellar density can be used in conjunction with evolutionary models to determine the mass and radius of the star. Alternatively, masses and radii can be determined for eclipsing binary stars based on well-known techniques if radial velocity data are available. We present masses and radii for the eclipsing binaries KIC 7821010 and KIC 9474969, which are targets that have great potential for seeking mass and radius confirmation through asteroseismological means. Stellar parameters for these systems were found using short cadence observations collected over the course of 25 months by the Kepler spacecraft as well as ground-based radial velocity and photometric data. Analyzing the eclipses and radial velocity data, we find mass and radius measurements accurate at the ~1% level. We compare our results with mass-radius relations from stellar evolutionary models. Finally, we compare our results with preliminary mass and radius measurements from asteroseismology. We acknowledge support from the National Science Foundation via the grant AST-1109928.

155.24 – Mass Transfer and Tidal Dynamics in White Dwarf Binary Systems

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Compact white dwarf (WD) binary systems (with orbital periods ranging from minutes to hours) can produce a variety of interesting astrophysical objects (e.g., type Ia supernovae, AM CVn systems, R Cor Bor stars, sdB stars) upon the onset of mass transfer. These systems are driven toward Roche lobe overflow by the emission of gravitational radiation, but it is not known whether the mass transfer will be stable (forming an Am CVn system) or become unstable (resulting in a merger). We analyze how the combined effects of mass transfer and tidal torques affect the evolution of these systems by creating numerical models with the MESA stellar evolution program. Using new calculations of the tidal torque in rotating WDs, we predict the outcome of mass transfer in these systems as a function of the masses of the WD components. We find that the stability of mass transfer depends primarily on the peak mass transfer rate near the period minimum, which is highly dependent on the WD masses and on the strength of the tidal torques. Except for low WD accretor masses, the tidal torques are insufficient to significantly increase the stability of mass transfer. We find that mass transfer is generally unstable for WD donor masses greater than about 0.25 solar masses, and that the 12 minute system SDSS J0615 will end its inspiral in a WD merger, likely producing an R Cor Bor star.

155.25 – A Physical Mechanism for State Transitions in Black Hole X-ray Binaries

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We present an accretion cycle that explains state transitions and many other observed phenomena in black hole X-ray binaries. This model is based on the process of disk tearing, where individual rings of gas break off the disk and precess effectively independently. The disk breaks within the radius where the Lense-Thirring precession is stronger than the local disk viscosity. The complete disk tearing process occurs in the intermediate state during the outburst rise stage as follows. Angular momentum cancellation of adjacent gas rings causes prompt infall onto an inner accretion disk. This sudden increase in mass accretion rate onto the black hole provides the conditions for the ejection of a transient jet. Interior to the disk break radius, a dynamic corona naturally forms from the shock-heated gas that does not cool effectively after the counter-rotating rings interact. The system then enters the high/soft state when the inner disk aligns with the black hole spin vector out to beyond the disk break radius, which halts disk breaking. We highlight the implications of this model for quasi-periodic oscillations and the disk-jet-corona coupling.

155.26 – Constraints on decreases in Eta Carinae's mass loss from 3D SPH simulations of its binary colliding winds

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Recent work suggests that the mass-loss rate of the LBV primary star in the massive, highly eccentric (e~0.9) colliding wind binary Eta Carinae dropped by a factor of 23 between 1999 and 2010. We present results from large- (±1545 au) and small- (±155 au) domain, 3D smoothed particle hydrodynamics (SPH) simulations of Eta Car's colliding winds for three primary mass-loss rates (2.4, 4.8, and 8.5 × 10^4 Msun/yr), investigating the effects on the dynamics of the binary wind-wind collision (WWC). These simulations include orbital motion, optically thin radiative cooling, and radiative forces. We find that the primary' mass-loss rate greatly affects the time-dependent hydrodynamics at all spatial scales investigated. The simulations also show that the post-shock wind of the companion star switches from the adiabatic to the radiative-cooling regime during periastron passage. This switchover is caused by the encroachment of the wind of the primary into the acceleration zone of the companion's wind, plus radiative inhibition of the companion's wind by the super-luminous primary. The SPH simulations together with 1D radiative transfer models of the stellar spectra reveal that a factor of two or more drop in primary mass-loss rate should lead to substantial changes in numerous multiwavelength observables. Recent observations are not fully consistent with the model predictions, indicating that any drop in mass-loss rate was likely by a factor < 2 and occurred after 2004. We speculate that most of the recent observed changes in Eta Car are due to a small increase in the WWC opening angle that produces significant effects because our line-of-sight to the system lies close to the dense walls of the WWC zone. A modest decrease in primary mass-loss rate may be responsible, but changes in the wind/stellar parameters of the companion cannot yet be fully ruled out. We suggest observations during Eta Car's next periastron in 2014 to further test for decreases in mass-loss rate. If the primary's mass-loss rate is declining and continues to do so, the 2014 X-ray minimum should be even shorter than that of 2009.

155.27 – Constraints on Common Envelope Magnetic Fields from Observations of Jets in Planetary Nebulae

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The common envelope (CE) interaction describes the swallowing of a nearby companion by a growing, evolving star. CEs that take place during the asymptotic giant branch phase of the primary and may lead to the formation of a planetary nebula (PN) with a post-CE close binary in the middle. We have used published observations of masses and kinematics of jets in four post-CE PN to infer physical characteristics of the CE interaction. In three of the four systems studied, Abell 63, ETHOS 1 and the Necklace PN, the kinematics indicate that the jets were launched a few thousand years before the CE and we favour a scenario where this happened before Roche lobe overflow, although better models of wind accretion and wind Roche lobe overflow are needed. The magnetic fields inferred to launch pre-CE jets are of the order of a few Gauss. In the fourth case, NGC 6778, the kinematics indicate that the jets were launched about 3000 years after the CE interaction. Magnetic fields of the order of a few hundreds to a few thousands Gauss are inferred in this case, approximately in line with predictions of post-CE magnetic fields. However, we remark that in the case of this system, we cannot find a reasonable scenario for the formation of the two jet pairs observed: the small orbital separation would preclude the formation of even one accretion disk able to supply the necessary accretion rate to cause the observed jets. Additional and improved observations of post-CE PN will provide a powerful tool to constrain the CE interaction.

155.28 – Hydrodynamic Simulations of AGB Binaries in Eccentric Orbits

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Several nebulae may have been formed by a binary interaction between an Asymptotic Giant Branch (AGB) star and a more compact companion in eccentric orbits. One such example is the peculiar nebula OH231.8+4.2 where a 3-M™ Mira is in a binary system with a main sequence A-type star and both are surrounded by a spectacular bipolar reflection nebula. We perform three, 3 dimensional hydrodynamic simulations of a binary system consisting of a 3 M™ AGB star and a main sequence companion with mass between 1.4 and 2.0 M™ in an eccentric orbit. The orbit is set up so that the separation at periastron is twice the radius of the AGB star. Tidal stretching causes mass loss from the AGB star, and we find that about 0.01 M™ of AGB envelope is captured by the companion. The orbits are altered in the process, and the companion star is captured by the AGB star in one or two more passages, forming a common envelope system. Only at this time, as the main sequence companion spirals in through the AGB star, is most of the envelope mass expelled from the system, sending the AGB star onwards in its evolution towards the white dwarf regime. A larger periastron separation results in no mass being transfered or expelled, while a smaller separation results in a faster capture of the companion. If the nebula of OH231.2 were formed during such a periastron passage event, as has been suggested, we would not find a Mira at its center today. Finally we create a synthetic light curve, to show how this could look if observed.

155.29 – Constraints on Inspiralling Binaries from First LWA Data

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The merger of a binary neutron star pair is expected to generate a strong transient radio signal. This emission will be strongest at low-frequencies and will disperse as it transverses the interstellar medium, arriving at Earth after coincidentally emitted gravitational or (higher frequency) electromagnetic signals. The rate of compact object merger events is poorly constrained by observations. The first station of Long Wavelength Array (LWA-1) telescope is a low-frequency radio telescope located near Socorro, NM, which is sensitive to a frequency range of 10-88 MHz. I will discuss the sensitivity of LWA-1 to transient radio emission from binary neutron star mergers and a limit set by LWA-1 observations to constrain the rate of such merger events.

155.30 – The Kozai Mechanism and Black Hole Binaries in Galactic Centers

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We use numerical simulations to explore the evolution of stellar-mass black hole binaries (BHBs) inside the radius of influence of supermassive black holes (SMBHs) in galactic centers. In this region the evolution of binaries is dominated by perturbations from the central SMBH. In particular, the Kozai mechanism trades relative inclination of the BHB to the SMBH for eccentricity of the BHB, and if the orientation is correct, can bring the BHB to an eccentricity of 1. At very high eccentricities, gravitational wave (GW) emission from the BHB can become efficient, causing the members of the BHB to coalesce. We will report results from N-body simulations combined with semi-analytic approximations. Our results have implications for the possibility of detection of GW emission by advanced LIGO as well as the overabundance of low mass X-ray binaries in the galactic center.

155.31 – Disk-jet coupling in the Galactic black hole X-ray binary MAXI J1836-194

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There is a universal connection between the accretion and ejection phenomena that are observed in black holes across the mass scale. Quantifying this relationship is the first step in understanding how jets are launched, accelerated and collimated. X-ray binaries are ideal systems to study this relationship, as they evolve on human timescales. In outburst, their luminosities increase by several orders of magnitude, with the thermal X-ray emission from the accretion disk and the radio emission from the relativistic jets undergoing dramatic, coupled changes. We present the results of our multiwavelength radio through to X-ray observations of the Galactic black hole candidate X-ray binary MAXI J1836-194 during its 2011 outburst. We find that this system has a near face-on accretion disk with the jet, that is pointed almost directly towards us, accounting for ~6% of the total energy output of the system early in the outburst. We observed the frequency of the transition from optically thick to optically thin synchrotron emission in the jet spectrum evolve by ~3 orders of magnitude as the jet gradually switches on and off on a timescale of a few weeks. This evolution does not appear to follow the expected positive relation with source luminosity. Instead the jet break shifted to higher frequencies as the source luminosity decreased and is likely coupled to the accretion flow in a more complex way. We find the region where the jet is accelerated up to relativistic speeds occurs at much larger distances from the black hole than previously thought and does not scale with the inner radius of the accretion disk. Our simultaneous, high cadence observations provide an unprecedented insight into the accretion processes occurring during an outburst, allowing us to observe the compact jet evolve and the corresponding changes within the accretion regime. This has implications for the launching of jets on all scales, from X-ray binaries to their larger-scale analogues, AGN.

155.32 – An Optical Survey for Black Holes in the Kepler Field

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Black holes and neutron stars represent the final evolutionary stages of the most massive stars, and as such are a fossil record of high-mass stellar evolution in the Milky Way. Black holes and neutron stars are ideal laboratories to test General Relativity in the strong field limit. The number of such objects in the Milky Way is not precisely known, but there are roughly one billion neutron stars in the galaxy based on the observed numbers of radio pulsars with corrections for the many observational biases, and about 100 million black holes based on the behavior of the Initial Mass Function at high stellar masses. All of the known steller-mass black holes (and a fair number of neutron stars) are in "X-ray binaries" that were

discovered because of their luminous X-ray emission. The requirement to be in an X-ray binary that has recently exhibited X-ray activity places strong observational biases on the discovery rate of stellar-mass black holes. Thus the 21 X-ray binaries that have confirmed black holes represent the tip of the iceberg. We have therefore began an optical survey using Kepler data that may uncover several black holes and neutron stars in both "quiescent'" X-ray binaries and "pre-contact" X-ray binaries. Any such discoveries will be of interest in their own right. In addition, the rate of such objects uncovered in our survey (or even the lack of discoveries) will place meaningful constraints on the formation theories of low-mass X-ray binaries and thus compact objects. We present here a progress report of our work so far, including techniques we use for light curve classification and the identification of the variability type. We gratefully acknowledge support from NASA via the grant NNX13AF23G.

155.33 – Examining XMM Observations in the Galactic Bulge Survey Region

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Contributing teams: The Galactic Bulge Survey Collaboration

The VXMM catalog was created in an effort to find help find low mass X-ray binaries (LMXBs) as part of the Galactic Bulge Survey (GBS). VXMM consists of XMM-Newton detections made in the GBS region, two 6x1 degree regions 1 degree above and below the Galactic plane. The goal of the project was to find GBS X-ray sources that exist in XMM observations in order to classify them. The XMM data were downloaded from NASA's database. Source detection was conducted on the filtered data sets using the 2XMM Serendipitous Survey as a guideline for the procedure but incorporating more recent data than 2XMM. The sources detected make up the VXMM catalog, which was used to cross reference with the GBS catalog to find GBS sources in the XMM data. In total the VXMM catalog found 107 GBS sources also detected by XMM. The spectra of several of these sources were examined to see which could be classified based on the XMM data. We focus on CX13 as it was the brightest unclassified GBS source detected by XMM. CX13 was determined to not be an active star as its temperature would to be high. Using a power-law model fit an LMXB was ruled out, as was a background AGN after the variability power spectrum was analyzed. The most likely remaining interpretation of its X-ray spectrum and variability is that it is an absorbed magnetic cataclysmic variable. This work is supported by the National Science Foundation under Grant No. AST-0908789. Vicente Estrada-Carpenter also acknowledges support from the REU Site in Physics and Astronomy (NSF Grant No. 1262890) at Louisiana State University

155.34 – An Improved Limit on the Orbital Period Derivative of the LMXB, UW CrB

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We present new broad-band optical photometry of the low mass X-ray binary (LMXB) UW CrB on four consecutive nights in June 2013. These data were obtained at the 2.1-m telescope of McDonald Observatory, with a time resolution of 10s, and cover a bit more than one orbital cycle each night. The light curves display partial eclipses of the accretion disk by the donor star that vary both in depth and orbital phase. Analysis of new eclipses in conjunction with published eclipse timings are well fitted with a linear ephemeris. We derive an upper limit on the time derivative of the orbital period, based on the best fit quadratic ephemeris and discuss its implications on the average mass transfer rate. By including the newly observed type I bursts with published bursts in our analysis, we find that bursts are not observed between 0.93 and 0.07 phases, i.e. they are not observable during partial eclipses of the disk.

155.35 – Simultaneous Filter Photometry of V1727 Cygni

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We present high speed optical photometry of the low mass X-ray binary V1727 Cygni. Simultaneous observations were obtained during five consecutive nights in 2013 using McDonald Observatory's 2.7-m and 2.1-m telescopes using u' and R filters respectively. There is very little variation in the u' intensity. The R data displays night to night and orbital period variations. We discuss constraints on system properties provided by these multi-filter data. This program is funded by NSF grant 0958783.

155.36 – Clump Accretion in Supergiant Fast X-Ray Transients

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Supergiant Fast X-Ray Transients (SFXTs) are a subclass of High-Mass X-Ray Binaries that consist of a neutron star and OB supergiant donor star. These systems display short, bright x-ray flares lasting a few minutes to a few hours with luminosities reaching 10^{36} erg/s, several orders of magnitude larger than the quiescent luminosities of 10^{32} erg/s. The clumpy wind hypothesis has been proposed as a possible mechanism for these transient flares; in this model, a portion of the stellar wind from the donor star forms into clumps and is accreted onto the neutron star, inducing flares. We use high-resolution 3D hydrodynamic simulations to test the clumpy wind hypothesis, tracking the mass and angular momentum accretion rates to infer properties of the resulting x-ray flare and secular evolution of the neutron star rotation. Our results are significantly different from the predictions of Hoyle-Lyttleton Accretion (HLA) theory, which assume steady, laminar, axisymmetric flow. For example, an off-axis clump initiated with an impact parameter greater than the clump radius (for which HLA predicts no effect) produces a small spike in mass accretion and induces a long period of disk-like flow that dramatically reduces the accretion rate below the steady HLA value. The result is a brief, weak flare with a net decrease in total accreted mass compared with steady wind accretion accompanied by a substantial accretion of angular momentum.

155.37 – Swift Optimized Strategy for Supergiant Fast X-ray Transients Study

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Contributing teams: Swift

Supergiant Fast X-ray Transients (SFXTs) are HMXBs with OB supergiant companions and are known for hour-long X-ray outbursts characterized by 3-5 orders of magnitude luminosity increases. Our Swift Supergiant Fast X-ray Transients Project, active since 2007, has taken advantage of Swift's flexible scheduling for a systematic investigation on both the SFXT bright flares which triggered the Burst Alert Monitor (BAT) with fast X-Ray Telescope (XRT) follow-up (1-2 min repointing time), and the emission outside the bright outbursts with XRT regular monitoring of several SFXTs and candidates with 2-3 observations per week (1-2 ks) for at least one year per source. This has allowed us to study for the first time broadband spectra of SFXT outbursts, to prove that timescales of source activity during outburts are of the order of weeks, to determine long-term properties of SFXTs, and to obtain an assessment of the fraction of the time these sources spend in each luminosity phase (outbursts, intermediate level, and quiescence) and their duty cycle of inactivity by means of very sensitive and non-serendipitous observations. We summarize the results achieved to date with our observing strategy and focus on the time resolved broadband spectral analysis of the 2011 and 2013 Swift detected outbursts of IGR J08408-4503, carried out with different spectral models, including the COMPMAG model specifically dedicated to the physical framework of accretion at the polar cap of a neutron star with a high magnetic field (>= 1E12 G), expected to be typical of these accreting systems.

155.38 – X-ray Polarization Properties of High Mass X-ray Binaries

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Polarization allows for sensitive tests of the geometry of astrophysical sources, on scales which are far too small to be imaged directly. X-ray polarization is of particular interest because it is almost entirely unexplored observationally, and because of the inherently non-thermal and non-spherical nature of many cosmic X-ray sources. In this paper we discussthe scientific motivation for X-ray polarimetry. We also present models for the X-ray polarization properties of High mass X-ray Binaries (HMXBs). These are these are binary systems in which a black hole or neutron star radiates due to accretion of gas supplied from a companion, and the dominant gas component comes from a strong stellar wind from a supergiant companion star. In these sources the stellar wind can be ionized and gravitationally focussed by the X-rays and gravity of the compact companion, and at the same time the dynamics close to the compact object play a key role in the accretion rate and hence in the X-ray output and other properties. Our models take into account the properties of the stellar wind and accretion flow: its dynamics, ionization and heating under the combined influence of the companion star and the compact object. Also, the non-LTE opacity properties of the wind, and the transfer of X-ray photons from the compact object through the wind. These predictions indicate how future measurements of X-ray polarization from high mass binaries can be used to probe the geometry and dynamics of the gas in these systems and in wider classes of sources.

155.39 – Orbital variability and magnetic field of Centaurus X-3 with Suzaku

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Centaurus X-3 is a binary system consisting of an 4.8 s X-ray pulsar and an O-type supergiant. Suzaku observed the source over one full binary orbit of 2.1 days in 2008 December. The 1-10 keV XIS and 10-30 keV PIN lightcurves show high flux in the first half of the orbit and low flux interrupted by flares in the second half. Based on the hardness evolution, we selected three time intervals for spectra lanalysis in the range of 1-50 keV: a long, bright, relatively unabsorbed part during the first half of the orbit as well as the partially absorbed rise and the relatively unabsorbed peak of a flare in the second half. A thermal Comptonization model (compTT) provided a better description than different phenomenological cutoff powerlaw models. The long, bright part allowed for the best spectral state selected measurement of the cyclotron parameters so far, and led to a B-field value of 3.4×10^{12} G. We compare this result to earlier measurements and discuss a possible luminosity dependence and its implication on source distance. The rise and peak of the flare were also well described by a thermal Comptonization continuum with additional partial covering absorption during the rise. We interpret this in terms of a clumpy wind structure. Future work includes pulse phase resolved spectroscopy, particularly of the cyclotron line, as well as spectral analysis of the low flux inter-flare spectra to check for indications of Compton scattering.

155.40 – Spectral Modeling of the Comptonized Continua of Accreting X-Ray Pulsars: Recent Progress

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We are undertaking a program to analyze the X-ray spectra of the accretion flows onto strongly magnetic neutron stars in high mass binary systems such as Her X-1, Cen X-3, and LMC X-4. These accreting pulsars typically have X-ray spectra consisting of broad Comptonized cutoff power-laws. Current theory suggests these X-ray spectra result from the impact of the high-velocity magnetically channeled plasma accretion flows onto the surfaces of the neutron stars. The flows have such high energy density that shocks developing in the plasmas can be radiation-dominated. These X-ray pulsars often, but not always, show cyclotron resonant scattering features implying neutron star surface magnetic field strengths above 10^{12} G. Over the past few years a number of studies have reported both positive and negative correlations of the cyclotron line energy centroids with X-ray luminosity in a number of pulsars. However, the detailed analysis of the cyclotron line centroids suffers from the lack of a robust model for the Comptonized X-ray continuum upon which the cyclotron lines are superposed. We discuss in this presentation our progress in developing tools for the analysis of the X-ray spectra formed in these systems. The range of parameter conditions presented by the many known real accreting pulsar systems substantially exceeds that of the limited set of pulsars on which the original analytic model of Becker and Wolff (2007) was validated. In the high temperature optically thick plasmas, the processes of bremsstrahlung emission from the hot plasma, black body emission from a thermal mound near the neutron star surface, and cyclotron emission from electrons in the first Landau excited state, all contribute to the total local photon population in the shock structure. We discuss our strategy for numerically accounting for the relative contribution to the full X-ray spectrum made by each of these physical processes. Solving for the integrated spectrum involves numerical integrations of complicated analytic series that presents different challenges in each of the three cases of cyclotron, black body, and bremsstrahlung emission. We discuss the issues involved for each physical process.

155.41 – Looking for Periodicity in X-Ray Emission Data

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X-Ray Binaries are systems in which matter falling from one component of the system to the other releases energy in the form of X-Rays. We created an algorithm which uses Pearson's Chi-Squared test to look for periodicity in X-Ray emission data from NASA's Swift Burst Alert Telescope (BAT) 58-Month Hard X-Ray Survey. We use the known High Mass X-Ray Binary J1647.9-4511B to test our program over a range of periods, bins and energy bands and verify the true period. Results are discussed.

155.42 – The Two-Faced Behavior of XTE J1946+274 Revealed by Suzaku

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We present a timing and spectral analysis of the X-ray pulsar XTE J1946+274 observed with Suzaku during the end of a weak outburst in 2010 October, and a comparison with previous results. XTE J1946+274 is a transient with a Be-type companion and a neutron star with a 15.8 s pulse period and a 169 d orbit. Despite large differences in flux, we observe a pulse-profile consistency between Suzaku , and RXTE data from two brighter outbursts in 2010 and 1998. We also discuss a pulse profile similarity with A 0535+26 . The X-ray spectrum can be well described by a Fermi-Dirac cutoff power law model along with a narrow Fe K-alpha fluorescence line at 6.4 keV. The flux of the iron line is consistent with the continuum vs. line flux correlation observed in other outbursts and we discuss the line-forming region. We also find evidence for the presence of a Cyclotron Resonance Scattering Feature (CRSF) at 35 keV, which was also previously detected in data from the bright outburst in 1998. The change in luminosity implies a change in the accretion regime from supercritical (1998) to subcritical (2010), along with a change in the structure of the accretion column, contrary to the consistency seen in the pulse profiles and the constant CRSF energy. XTE J1946+274 has two outbursts per orbit. We discuss how these aspects raise questions about our current knowledge of accretion in Be-systems and of neutron star accretion-column models.

155.43 – X-ray and Ultraviolet Spectral Evolution of LMC X-3 During Normal and Anomalous Low States

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The bright black-hole X-ray binary LMC X-3 is a lower-mass high-mass X-ray binary with a 1.7 day orbital period. Both the X-ray source and its bright optical/UV companion show non-periodic high amplitude variability on timescales much longer than this (100-300 days). Previous observations do not present a clean picture of whether Roche-lobe overflow or wind accretion is the dominant mechanism driving this dramatic long-term variability. RXTE monitoring has recently revealed that LMC X-3 undergoes surprising anomalous low states (ALSs), during which the X-ray source is virtually indistinguishable from background, and stays low for three to six months at a time (Smale & Boyd 2012). The cause of these ALSs is not known. NASA's Swift telescope is uniquely capable of shedding light on this mystery by providing simultaneous X-ray, UV, and optical observations of the source during its normal long-term variability. Swift has obtained simultaneous multiwavelength data at a variety of X-ray fluxes while the system was displaying its normal variability state, as well as dense monitoring during an ALS and during a recent normal low state. Comparison of X-ray spectral modeling with the UV variability offers the best chance to disentangle the various sources of UV radiation in the system. We present the results of spectral fitting of the Swift XRT and, when available, XMM/Newton spectra which probe the accretion state of the black hole. We compare these with the UV flux arising from the stellar surface and outer accretion disk, searching for correlations and lags that could reveal whether a substantial fraction of the UV flux is due to reprocessing of X-rays within the system, or arises from another mechanism.

155.44 – The First Suzaku Observation of 4U 1538-522

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We present results from the first Suzaku observation of the high mass X-ray binary 4U 1538-522. The broad-band spectral coverage of Suzaku allows for a detailed spectral analysis, characterizing the cyclotron resonance scattering feature at $22.5^{+0.2}_{-0.4}$ keV and the iron Kα line at 6.417 ± 0.006 keV, as well as placing limits on the strengths of the iron Kβ line and the iron K edge. We track the evolution of the spectral parameters both in time and in luminosity, notably finding no significant correlation between cyclotron line energy and luminosity. A dip and spike in the lightcurve is shown to be associated with a factor of ~2 increase in column density along the line of sight, as well as significant variation in the underlying continuum, implying the accretion of a overdense region of a clumpy stellar wind. A phase-resolved analysis is also presented, with most spectral parameters of interest showing significant variation with phase. Notably, the line-of-sight column density drops drops signficantly at pulse maximum, while the cyclotron line energy reaches a maximum. We discuss the implications of these findings in the context of recent work in the area of cyclotron resonance scattering feature formation.

155.45 – Multiwavelength Analysis of the Gamma-ray Binary LS I +61 303

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We present a multiwavelength analysis of the ?-ray binary system, LS I +61 303. LS I +61 303 is a high-mass X-ray binary (HMXB) that also emits strongly at ?-ray energies. We have analyzed five years worth of data from the Fermi Gamma-ray Observatory and find a clear periodicity of 26.7 days in the GeV flux, matching previous studies. The Fermi data also show evidence for long-term modulation matching the previously reported 1667 day (4.5 year) super-orbital period. We also compare the Fermi data to variations in Hα spectra taken at different super-orbital phases and look for correlations between the optical and ?-ray emission. LS I +61 303 has long been thought to consist of a classical Be star as the primary along with a compact secondary (neutron star or black hole); however, we present new optical spectroscopy that suggests the star is more evolved than previously thought. The results of this study bring the properties of the binary system into better focus so that we may begin to understand the true nature of this high-mass gamma-ray binary system.

155.46 – Spectral Analysis of the Gamma-ray Binary Candidates 2FGL J0642.9+0319 and 2FGL J1151.5-1347

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2FGL J0642.9+0319 and 2FGL J1151.5-1347 are gamma-ray binary candidates with proposed orbital periods of 21.5 and 76 days, respectively. Using data from the Fermi Large Area Telescope (LAT) taken between 2008 and 2013, the sources were fit to spectral models and their gamma-ray spectra were obtained. The data analysis tools from the Fermi Science Support Center (FSSC) were used for a binned likelihood model of all the sources within a 30 degree region of interest. Convergence of the likelihood function was obtained for both sources, but further analysis is needed to improve each fit. From the initial convergence, the modeled flux was calculated to be $4.3 \pm 0.1 \times 10^{-8}$ photons cm-2 s-1 for 2FGL J0642.9+0319 and $6 \pm 2 \times 10^{-9}$ photons cm-2 s-1 for 2FGL J1151.5-1347. However, our light curves using a binned likelihood analysis do not confirm their proposed periodicity. We would like to thank the National Science Foundation for the grant AST-1109247 and REU site grant PHY-0849416.

155.47 – Standing Shock Instability in Advection-Dominated Accretion Flows

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There is strong evidence that quasi-periodic oscillations (QPOs) behavior exist in the bright white dwarfs (WD), neutron stars (NS), black hole binaries (BHB), intermediate mass black holes (IMBH), and supermassive black holes (SMBH). The phenomenological features of these QPOs suggest that such oscillations can be a probe of the accretion processes in the inner regions of the accretion disks around the central compact objects, and that disk-shock instabilities may generate the QPOs observed in these compact objects. It has been known for sometime that the velocity profiles of an inviscid advection-dominated accretion flows (ADAFs) can display a shock-free, one possible shock, or two possible shock (inner shock or outer shock location) solutions depending on the values of the energy and angular momentum per unit mass in the gas supplied at large radii. For the case where two possible shock locations can be found, however, the flow can only pass through the inner shock or the outer shock but not both. Since there is no priori reason to choose a particular location, it is a necessity to do a stability analysis of the standing shock waves to determine a preferred stable solution. Following Chevalier & Imamura (1982) linearization method and employing Nakayama (1992, 1994) instability boundary conditions, we find that both the velocity profiles that exhibit pre-shock deceleration and pre-shock acceleration are always unstable to the first-order mode with zero frequency of oscillation, and higher order modes with nonzero frequencies of oscillations become increasingly unstable when the shock locations moves away from horizon as the disk height expands. Our model also predicts the QPOs' ratios 2:3 and 3:5 that are believed to occur in solar and supermassive black hole candidates, for example in GRS 1915+105 and SgrA*, respectively. The QPOs ratios, in general, have been suggested to be related to the spin of the compact objects.

155.48 – Results of the Swift Monitoring Campaign of the X-ray Binary 4U 1957+11

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We present the results of a uniform spectral analysis of 26 Swift/XRT observations of the X-ray binary system 4U 1957+11 made between 2007 July 01 - 2011 November 25. All 26 spectra are predominantly thermal, and can be modeled well with emission from an accretion disk around a black hole. In addition to traditional chi-squared fitting we also used a Markov

Chain Monte Carlo (MCMC) technique applied simultaneously to all 26 spectra to explore the 54 dimensional combined model parameter space. Assuming a black hole accretor, the MCMC results strongly constrain the orbital inclination on the binary system, color correction factors to the individual spectra, and the density of the intervening absorption column. Additionally, our analysis strongly prefers a rapidly rotating hole with near maximal prograde spin, strengthening previous X-ray results. We find distances less than 5 kpc are unlikely and not only ruled out based on our analysis but also from other independent observations. We will also present correlations among model parameters explored by the MCMC technique.

155.49 – The dynamics of jets in circum-binary environment of HMXBs

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The jet of a microquasar interacts with the interstellar medium, generating characteristic signatures that may unveil important properties of the compact object. For High Mass X-ray Binaries (HMXBs), the presence of the OB type companion star should be taken into account in studying the interaction of the jets with the ambient medium. The strong wind from the companion star dominates in the circum-binary environment, forcing the jet to be bent with characteristic inclination angle which depends on parameters of the jet and the stellar wind. We perfom 3 dimensional hydrodynamic simulation in order to illuminate the relationship between the angle and the jet power, opening angle, and wind power. In the small jet bending approximation, we derive an analytic solution for the bending angle, which can be used to constrain observational parameters in HMXBs.

155.50 – A Rare Eclipse Event: The Eclipsing Variable Radio Source b Per

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In 2012 we arrived at the 221st AAS Meeting in Long Beach California to present recent Navy Precision Optical Interferometer observations of the variable radio source b Per (HR1324) in hopes of soliciting photometric and spectroscopic observations to confirm a rare edge-on eclipse of the AB-C component. We are happy to return a year later to confirm the orientation of the edge-on AB-C component that was observed in eclipse both photometrically and interferometrically very near the original eclipse prediction date. This eclipse prediction represented the half-way point of the C-components journey around the close AB pair and this was observed to take place during the period of February 7-11, 2013, from ingress to egress. The period of the C component has been measured spectroscopically to be roughly 702.9 days with the next potential eclipse(s) predicted to occur during the period of April 1-11 2014. Here we present the latest observational data of the b Per system, including spectroscopic, photometric and interferometric observations to further support the need of an observing campaign to help further unlock the secrets of this very interesting, astrophysically complex system. Due to the rare orbital orientation of this triple system it may be possible to further constrain the properties of the close binary pair aiding in the understanding of the evolutionary stages of each of the components.

155.51 – UBVRI Observations, Analysis and Spectra of the Mature W UMa Contact Binary, V444 And

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We present the first precision UBVRI light curves, synthetic light curve solution, a period study and spectra for the V444 Andromedae, an FO V contact W UMa binary. Observations were taken at Lowell Observatory with the 0.81-m reflector from 28 through 30 September 2012 and the spectra at Dominion Astrophysical Observatory's (DAO) with the 1.8m telescope on 22 July 2013 at a resolution of 60 Å/mm. We determined three times of minimum light from these observations, JD Hel Min I = 2456199.0239±0.0011, 2456199.9616± 0.0015 and JD Hel Min II = 2456198.7907±0.0005. From our period study we determined an improved linear ephemeris, J.D. Hel Min I = 2456199.9618±0.0003d + 0.46877942±0.00000005×E The period has been stable over the past 9.6 years (~7500 orbits). After an extensive mass ratio-search, the lowest residual mass

ratio was found to be 0.48. Our final Wilson-Devinney Program computation determined that the system is an A-type W U Ma contact binary with a fill-out of nearly 51%. Despite its temperature (7200-7300 K), two magnetic spots were found on the primary component, a 10 degree radius equatorial dark spot, T-factor=0.88 and a 23 degree radius near polar hot spot, T-factor=1.10. The component temperature difference is only ~80K. These parameters tell us that the V444 And is a mature solar type binary.

155.52 – Productive Observing with a Small Telescope at an Urban Site

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In the modern era keeping smaller telescopes in non-optimal sites relevant requires significant preparation and planning. The "Great Equatorial," the largest telescope in the world (1873-1880) at the U.S. Naval Observatory, discovered the two moons of Mars in 1877. Since then, it's primary observing program has been the observation of double stars. While the number of binary stars appropriate for orbital analysis with a 26inch refractor at an urban site is small, the telescope can observe approximately 38,500 of the 127,758 known pairs in the sky. Many of these pairs fall into a class of double we call "neglected," that is, no measures have been obtained in the last ten years or the have never been confirmed. These measures can eventually establish whether the pair is a chance alignment or a bona fide binary star. Whether some of these more tenuous doubles are physical or not has implications for Galactic dynamics. Observations we can make with the 26inch are those which don't need to be made at greater expense at remote observatories with our speckle camera or through collaborations with other astronomers. However, these other observations still need to be made. The breadth of the USNO double star observing program is presented along with new "phase optimizer" software to ascertain when pairs need to be observed to improve the quality of their orbit significantly and with what telescope/technique.

156 – Variable Stars Poster Session
Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

156.01 – Sixty Thousand Periodic Variables from the Catalina Surveys

Andrew J. Drake[1], Matthew Graham[1], Stanislav G. Djorgovski[1], Marcio Catelan[3], Ashish A. Mahabal[1], Jose Prieto[4], Ciro Donalek[1], Eric J. Christensen[2], Stephen M. Larson[2], Andrea Boattini[2], Alex Gibbs[2], Albert D. Grauer[2], Richard Hill[2], Richard Kowalski[2], Jess Johnson[2], Frank Shelly[2], Gabriel Torrealba[3]
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We have performed an in-depth search for periodic variable stars within the photometry from the Catalina Surveys Data Releases. Our analysis reveals ~40,000 new periodic variable stars with brightness ranging from V=11 to 20, from a region covering ~20,000 square degrees on the sky. Each source is classified based on lightcurve morphology and multi-color photometry from WISE and SDSS. The variable stars discovered include eclipsing binaries, such as Algol, beta Lyrae, W UMa and WD+dM types, and pulsators including delta Scuti's, SX Phe, LPVs, RR Lyrae and Cepheids. We combine these sources with type-ab RR Lyrae from our prior analysis to produce a periodic variable catalog containing 60,000 stars. Using ~5,500 optical spectra from SDSS DR10 we determine the metallicities, surface gravities and radial velocities of the major types. The photometry, classifications and periods will all be made publicly available through the Catalina Surveys data release website.

156.02 – A catalog of 7000 optically faint periodic variable stars from the LINEAR survey

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We present a catalog of about 7000 optically faint periodic variable stars with light curves obtained by the asteroid survey LINEAR across 10,000 sq.deg. of the northern sky. The majority of these variables have not been cataloged yet. The sample flux limit is several magnitudes fainter than most other wide-angle surveys; the photometric errors range from 0.03 mag at r = 15 to 0.20 mag at r = 18. Light curves include on average 250 data points, collected over about a decade. The sample is dominated by 3900 RR Lyrae stars and 2700 eclipsing binary stars of all subtypes and includes small fractions of relatively rare populations such as asymptotic giant branch stars and SX Phoenicis stars. These publicly available (from https://astroweb.lanl.gov/lineardb/) large samples of robustly classified variable stars will enable detailed statistical studies of the Galactic structure and physics of binary and other stars, and can be used for training automated light curve classification methods. Details about this catalog are available in Palaversa et al. (2013, AJ 146, 101).

156.03 – Twinkle, Twinkle: Characterizing Variable Stars in Young Open Clusters

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The usefulness of identifying and characterizing variable stars has proven timeless since the first variable discovery in the sixteenth century. From distance calculations to binary star discoveries to development of stellar evolution theories, variable star observations have made, and continue to make, significant contributions to astronomy. Here we present the results of an ongoing investigation of four young open star clusters: ASCC 105, ASCC 109, Collinder 359, and IC 4665. Observations of the four clusters were collected with the Maria Mitchell Observatory's 17-inch reflecting telescope. The data collected were used primarily to characterize known variable stars and to identify new variables. Images of each of the four fields were also used to characterize non-variable members in order to refine estimates of the cluster's membership, distance, reddening, age, and chemical abundance. The main goals of the project were to determine these characteristics of the cluster fields to higher precision than previously measured, and to provide a foundational list of variable stars for future spectroscopic data collection.

156.04 – Identification of BY Draconis Variable Stars in ASAS Data

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A spreadsheet of 3,548 automatically classified candidate Cepheid variable stars in the ASAS (All Sky Automated Survey) photometry data was provided to members of the AAVSO (American Association of Variable Star Observers) for analysis.

However, it was known from the start that the computer filters had overpopulated the list, for example including Beta Cepheid stars in addition to Type I and Type II Cepheids. Patrick Wils investigated a small subset of the data using 2MASS, PPMXL, and ROTSE data and discovered that the vast majority of the 84 candidates he surveyed appeared to have been misidentified. The most common misidentification seemed to be of BY Draconis stars (spotted K and M dwarfs). In addition, since the light curves of Type II Cepheids are especially ambiguous in certain period ranges, this automatic classification of large photometric surveys is especially problematic for researchers seeking examples of this rarer type of star. The ongoing project described here is a systematic identification of candidate BY Draconis stars from among the 3,548 original candidates. The stars are being sorted using VSX (International Variable Star Index) information, for example to search for prior identification by other authors in the time since the initial population of the candidate list (as has been done using ROTSE data), along with infrared photometry (2MASS) and proper motion (PPMXL) data. An analysis of light curves and phase plots is the final step in identifying potential BY Draconis stars. The goal of this project is to submit updated identifications for these stars to the International Variable Star Index (VSX).

156.05 – Starspots on LO Pegasi, 2006-2013

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LO Pegasi is a K8 main-sequence variable of BY Dra type, exhibiting dark starspots on its surface which modulate its brightness as they are carried into and out of view by the star's rotation. We present the results of BVRI photometry obtained at Perkins Observatory in Delaware, OH from 2006-2013. The light curve shape and by implication the spot configuration is stable on a time scale of several months, but shows substantial year-to-year variations. In particular, the V modulation was a maximum of approximately 0.15 mag in June-July 2011, and a minimum of approximately 0.04 mag in 2012 and 2013. In addition, the mean brightness was lowest in 2012, suggesting the growth of a large spot on the visible rotation pole, which would simultaneously account for the small modulation and lowered mean brightness. In 2013, the mean brightness increased by about 0.05 mag compared to 2012, suggesting that the polar spot is shrinking in size.

156.06 – A Mid-Infrared Search for Variable Stars in the Milky Way Galaxy

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Contributing teams: the GLIMPSE team

Using the Spitzer Space Telescope and the onboard IRAC (Infrared Array Camera) instrument, we have matched 27,703,930 mid-infrared sources detected in the overlap regions of the GLIMPSE (the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire) (2004-2005) and Deep GLIMPSE (2012-2013) surveys. Most sources are measured at wavelengths of 3.6 and 4.5 microns with Galactic coordinates | l | < 65 deg and | b | < 1 deg. Of the matched infrared sources, 100,998 showed evidence of greater than 2 sigma variability in multiple bands in the same direction. We present an analysis of this population, presenting their magnitude, color, spatial, and environmental properties. We find two notable features. First, the population of variable stars is bimodal in apparent magnitude, with a minimum at m=9-10 mid-infrared magnitudes. Second, we find several factor-of-two spatial overdensities of variable stars at selected points along the Galactic plane. In addition, we present the 10-sigma variability list which contains 1060 variable stars, all of which were visually verified, and describe incidental discovery of several new proper motion stars. This work was supported by NSF REU Site Grant to the University of Wisconsin-Madison.

156.07 – Expanded RR Lyrae Search in the Southern Hemisphere with the La Silla-QUEST Survey

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We present the recent work of the La Silla-QUEST (LSQ) Variability Survey on RR Lyrae stars (RRLS) and their use as probes of galactic halo structure. While past RR Lyrae surveys with LSQ were limited to areas overlapping the Sloan Digital Sky Survey, in order to expand our survey beyond overlap with SDSS we select RRLS candidates on the basis of their B-R colors in the Palomar drift-scan survey. This enables the LSQ survey to cover the declination band from -24 to +25 deg. and all right ascensions except where the band is less than 18 deg from the galactic plane. The LSQ survey for both type ab and c RRLS is approximately 70% complete over the magnitude range 14 to 20 in V, which in directions of low interstellar extinction corresponds to distances from roughly 5 to 75 kpc. Results on galactic structure and Oosterhoff properties of Type ab and c variables will be presented for a subregion of the survey. This research has been supported by NSF grant AST-1108948 and DOE grant DE FG0 ER92 40704 to Yale University and by the Provost Office of Yale University.

156.08 – An Automated Search for RR Lyrae Stars in M5

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RR Lyrae variables are a type of pulsating, horizontal branch star. They are useful for the information they give on stellar evolution and because they serve as tracers for the conditions in which their host globular cluster was created. Their variability is also very distinctive in that they can undergo a change of about one magnitude in less than a day. Given that globular clusters have a large number of stars, it's useful to have a method that can search through this data automatically. Given certain input parameters, our code downloads data, cleans it, and employs the Lafler-Kinman method to search for periodicity, returning results complete with light curves for the sources that fall within a certain error threshold. Here we report the results of an automated search for RR Lyrae stars in the globular cluster Messier 5 using data from the Catalina Real-Time Transient Survey.

156.09 – Spectroscopic Identification and Metallicity Determination of RR Lyrae Variables in Sloan, with a New Metallicity Calibration Including High-Temperature Phase Regions

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RR Lyrae stars provide important distance markers for tracing out the metallicity and physical extent of tidal streams and the galactic halo. Here we present a method for potentially identifying a few thousand RRL stars by comparing low-resolution, single-epoch spectra from the Sloan Digital Sky Survey (SDSS) DR9. This method is tested against the heavily-sampled 'Stripe 82' of SDSS. We have also begun developing a new metallicity calibration that fills in the high-temperature regions in RR Lyrae phases for phase regions other than (and including) minimum light. Our calibration extends metallicity determinations provided by previous methods which were calibrated at minimum light only, and also has the potential for detecting shorter-period RRc stars. Phase information was taken from the MacAdam Student Observatory at the University of Kentucky, and the Moore Observatory at the University of Louisville. Spectroscopy was recorded at the University of Texas' McDonald Observatory. This spectroscopic data set builds on a metallicity standard that we discuss. Ultimately, this new calibration will allow the gleaning of more accurate metallicity information from spectroscopic data taken by surveys such as SDSS.

156.10 – Observations of Suspected RR Lyrae Variable Stars

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Our group is working on confirming variability of suspected RR Lyrae variables we have identified, and making follow-up observations of confirmed new variables. We developed a new method of detecting RR Lyrae variable stars using only a single epoch of both photometry and spectroscopy taken from the Sloan Digital Sky Survey (SDSS). The method takes advantage of clear departures from the template norm for stars that have photometry and spectroscopy taken out of phase. Over 1,000 stars have been identified as probable RR Lyrae stars, scattered across the halo and ranging from 14th to 20th

magnitude. This paper describes observations taken at McDonald Observatory by undergraduate students as part of this project. We will discuss how and why the method works, and our McDonald observations to confirm variability and obtain full lightcurves.

156.11 – A Mid-infrared Study of RR Lyrae Stars with the WISE Full-Sky Data Release

Tatyana Gavrilchenko[1], Christopher R. Klein[1], Joshua S. Bloom[1], Joseph Richards[1], Nathaniel Butler[2]
1. University of California, Berkeley, Berkeley, CA, United States. 2. Arizona State University, Phoenix, AZ, United States.

We present a group of more than 3,000 previously identified RR Lyrae variables well-observed with the Wide-field Infrared Survey Explorer (WISE). We explore how the shape of the generic RR Lyrae mid-infrared light curve evolves in period-space, comparing light curves in mid-infrared and optical bands. We find that optical light curves exhibit high amplitudes and a large spectrum of light curve shapes, while mid-infrared light curves have low amplitudes and uniform light curve shapes. From the period-space analysis, we hope to improve the classification methods of RR Lyrae variables and enable reliable discovery of these pulsators in the WISE catalog and future mid-infrared surveys such as the James Webb Space Telescope (JWST). We provide mid-infrared templates for typical RR Lyrae stars and demonstrate how these templates can be applied to improve estimates of mid-infrared RR Lyrae mean magnitude, which is used for distance measurement. This method of template fitting is particularly beneficial for improving observational efficiency.

156.12 – Changing Amplitudes: Detecting RR Lyrae Light Curve Shape Variations in the Galactic Disk and Inner Halo

Nathan M. De Lee[1, 2], Karen Kinemuchi[3], Joshua Pepper[4, 2], Joseph E. Rodriguez[2]
1. Univ. Nebraska Kearney, Kearney, NE, United States. 2. Vanderbilt University, Nashville, TN, United States. 3. Apache Point Observatory/New Mexico State University, Sunspot, NM, United States. 4. Lehigh University, Bethlehem, PA, United States.

In this poster we will discuss our ongoing program to use extant light curves from the Kilodegree Extremely Little Telescope (KELT) survey to find and characterize RR Lyrae (RRL) stars in the disk and inner halo of the Milky Way. RRL stars are of particular interest because they are standard candles and can be used to map out structure in the galaxy. The periods and shape of RRL light curves also contain information about their Oosterhoff type, which can probe galactic formation history, and metallicity respectively. Although there have been several large photometric surveys for RR Lyrae in the nearby galaxy (OGLE, NSVS, ASAS, and MACHO to name a few), they have each been limited in either sky coverage or number of epochs. The KELT survey represents a new generation of surveys that has many epochs over a large portion of the sky. KELT samples 60% of the sky in both northern and southern hemispheres, and has a long-time-baseline of 4-8 years with a very high cadence rate of less than 20 minutes. This translates into 4,000 to 9,000 epochs per light curve with completeness out to 3 kpc from the Sun. Recent results from both Kepler and ground based surveys results suggest that as many as 50% of RR Lyrae stars show long-term modulation of their light curve shapes (Blazhko effect). These stars combined with RRL stars that pulsate in more than one mode give a sample of objects that the KELT survey is uniquely suited to explore. This poster concentrates on a pilot project to examine RRL stars in a limited number of KELT fields. In particular, we focus on, detecting RR Lyrae, developing a light curve shape-metallicity relationship in the KELT band-pass, and some initial characterization of RRL with either amplitude-modulated or period-modulated light curves.

156.13 – Photometry of the Under Observed RR Lyrae Star GM Orionis

Justin Brown[1], Robert J. Boyle[1]
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We report photometric observations of the under-observed RR Lyrae variable star GM Orionis. Earlier observations show an inconsistency in the star's observed brightness, while the amplitude of variability has remained constant. We show photometry that has been collected over a three-year period demonstrating a continued increase in brightness. We discuss possible explanations.

156.14 – An Automated Search for RR Lyrae Stars in Globular Clusters

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The exotic properties of an RR Lyrae star provide a high level of interest to research in astronomy, and particularly for globular clusters. Therefore, the development of a fast and effective search algorithm was in order. We created an algorithm

that finds the period using the Lafler-Kinman search algorithm, which allows us to identify RR Lyrae stars, and then produces respective phase files. We then created an algorithm that plots all these files simultaneously and makes them instantaneously available to look through and classify. A systematic search was completed for RR Lyrae stars for all available globular clusters in the Harris Catalog. It was conducted using extracted light curve data from the Catalina Real-time Transient Survey (CRTS). I provide background on the project and report the results of the entire search.

156.15 – A Photometric Survey for Rapidly-Pulsating Hot Subdwarf Stars with SKYNET

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Hot subdwarf B stars (sdBs) are evolved stellar objects with high effective temperatures and large surface gravities. Theory shows that these stars were once red giants that were stripped of their outer H envelopes. How this stripping occurs is uncertain, although observations show binary interactions probably play a major role in this process. A small fraction of sdB stars exhibit rapid photometric oscillations; such pulsations are excellent tools for unraveling the structure and future evolution of these stars. We are currently surveying known sdB stars with the SKYNET telescope network to discover new pulsators. Here we discuss the details of our survey and present a handful of new variables that we have found.

156.16 – Asteroseismology of 23 pulsating stars in eclipsing binaries

Zhao Guo[1], Douglas R. Gies[1], Rachel A. Matson[1], Stephen Williams[1]
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We present light curve modeling and frequency analysis of 23 eclipsing binaries with pulsating components of delta Scuti or gamma Dor type. By combining the Kepler light curves with our spectroscopic analysis,we get accurate fundamental parameters like mass,radius,temperature,and age.From comparison with theoretical evolution tracks and pulsation frequencies calculated by MESA and GYRE,we attempt to identify the pulsation mode and further constrain these fundamental parameters. As an example, we show a preliminary asteroseismic modeling of KIC9851944. It is likely that both components are delta Scuti type pulsators. The dominant frequency peaks are identified as radial and dipole modes,tidally induced pulsations are also detected.Further theoretical modeling of tidal effect on oscillation frequencies is underway.

156.17 – Precision Asteroseismology of Compact Subdwarf B Stars using Kepler Observations.

Mike Reed[1]
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Kepler observations of pulsating subdwarf B stars (called extended horizontal branch stars in globular clusters) have presented a revolution in compact seismology. Prior to Kepler observations, the models were relatively unconstrained by observations because of a lack of mode identifications. Now, from extended Kepler observations, we have several means to constrain mode identifications including rotationally split frequency multiplets and overtone period spacings. With tens of periodicities identified, we can examine frequency-dependent overtones and with several years of Kepler observations, time-dependent examinations of pulsation amplitudes and frequencies is possible. This poster will review what has been discovered.

156.18 – The Brightening of the North Star: Has Polaris' Brightness Steadily Increased for Centuries and, perhaps, even Millennia?

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Polaris is arguably the best-known star in the Northern Hemisphere, since it lies within a degree of the North Celestial Pole. For much of human history, Polaris was highly regarded for its unchanging nature. However, we now know that Polaris is a Cepheid variable, undergoing ultra-low-amplitude pulsations. Thirty years ago, a paper in the Astrophysical Journal by A. Arellano Ferro announced that the amplitude of these pulsations was diminishing. This behavior was confirmed, and it was believed that soon enough Polaris would no longer be a Cepheid variable. We started photometrically monitoring Polaris in 1999 and discovered that the amplitude of pulsations had reached a minimum and was now, in fact, growing again. It was while gathering historic photometry for the amplitude study that we noticed the published magnitudes of Polaris were

systematically fainter, the further back in time the data went. This is an entirely unexpected behavior for a Cepheid variable, and one that we wanted to investigate further. We continue to observe Polaris to monitor the star's brightness, along with pulsation period and amplitude, and we have re-analyzed the historic studies of Polaris to validate the brightening. We have also obtained HST-COS UV spectra of Polaris for comparison to archival IUE data, to look for flux and/or temperature changes. We gratefully acknowledge support from NASA grant HST-GO-11726.

156.19 – Hydrogen Alpha Temperature Curves for 8 Classical Cepheids

Eric G. Hintz[1], Michael D. Joner[1]
1. Brigham Young Univ., Provo, UT, United States.

Over the last eight years we have developed a spectrophotometrically determined temperature index for the H-alpha spectral line. The spectra used in this study covered from the region of H-alpha to the region of H-beta and therefore we could measure the two indexes at the same time. These observations were then fully calibrated against a set of field stars, and stars from the Hyades, Pleiades, Coma, and NGC 752. As part of our observing program we have observed a number of classical Cepheids and built up sufficiently complete phased curves for a number of stars. We will present H-alpha and H-beta curves for 8 Cepheid variable stars. This list includes X Cygni, delta Cephei, CD Cygni, FF Aquilae, V473 Lyrae, FM Cassiopeiae, SU Cassiopeiae, and zeta Geminorum. We also have partial data on 4 additional Cepheid variables. We would like to acknowledge use of the 1.2-m McKellar telescope of the Dominion Astrophysical Observatory.

156.20 – Metallicity and Crowding Effects on the Cepheid Period-Luminosity Relation for M101

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1. Susquehanna University, Selinsgrove, PA, United States. 2. Carnegie Observatories, Pasadena, CA, United States.

The impact of metallicity on the Cepheid Period-Luminosity (P-L) relation is investigated using HST ACS V and I images of M101. Variations in the reddening-free Wesenheit parameter (W), which is employed as a proxy for luminosity, are examined as a function of the radial distance from the center of M101 (and thus metallicity). We determine that there is no dependence of the slope on metallicity. However, the intercept is found to depend on metallicity by ?VI = 0.33±0.12 mag/dex and ?VI = 0.71±0.17 mag/dex using 2 and 3 sigma rejection criteria, respectively. Sigma-clipping impacts the derived metallicity dependence, and the 2-sigma criterion applied likely mitigates blending, particularly in the crowded inner regions of M101. A metallicity-corrected distance for M101 is obtained from 619 Cepheids (μ = 28.96 ± 0.11), a result that agrees with the recently determined SN Ia distance. The metallicity effects described can be bypassed by working at near and mid-infrared wavelengths (e.g., the Carnegie Hubble Program).

156.21 – Measuring Stellar Rotation Periods Over Multiple Kepler Quarters

Justin Hyatt[1]
1. The University of Arizona, Tucson, AZ, United States.
Contributing teams: The University of Arizona Kepler Project Students

We present a study by the University of Arizona Kepler Project of the rotation periods of Sun-like stars in the Kepler field-of-view using photometric lightcurves from Kepler. Precise stellar rotation periods are critical for many analyses, including studies of stellar dynamo. The relation between age, rotational velocity and seismic activity provides information needed to model how the momentum is transferred between stellar layers and how the internal angular momentum and magnetic field changes over the life cycle of a star. We use various analyses of Kepler lightcurves to compute periodograms from which we determine the apparent rotational periods of stars. Kepler data is recorded over 16 discrete periods of time or quarters. Past studies have found stellar rotational periods by studying data from individual quarters or by comparing multiple quarters. In this project we stitch data from all 16 quarters together in sequence in order to improve our signal-to-noise ratio and to detect low frequency variation. We also compare our findings with the rotation periods calculated from individual quarters of data. Our rotational period measurements can work in conjunction with additional measurements, such as ages and activity levels of the sample, to provide insights into stellar models.

156.22 – Variable Circumstellar Disks of "Classical" Be Stars, Part 2

Cody Gerhartz[1], James W. Davidson[1], Karen S. Bjorkman[1], John P. Wisniewski[2]
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Circumstellar disks are common among many stars, all spectral types, and at different stages of their lifetimes. Among the near-main sequence "Classical" Be stars, there is growing evidence that these disks can form, dissipate, and reform, on timescales that are differ from case to case. We present data for a subset of cases where observations have been obtained

throughout the different phases of the disk cycle. Using data obtained with the SpeX instrument at the NASA IRTF, we examine the IR spectral line variability of these stars to better understand the timescales and the physical mechanisms involved. The primary focus in this study are the V/R variations that are observed in the sample. A complete run of all double-peaked velocity profiles in the sample is now complete. The second stage of our project is to examine a sample of star clusters known to contain Be stars, with the goal to develop a more statistically significant sample of variable circumstellar disk systems. With a robust multi-epoch study we can determine whether these Be stars exhibit disk-loss or disk-renewal phases. The larger sample will enable an understanding of the prevalence of these disk events.

156.23 – Photometric Variability in Proto-Planetary Nebulae: Extending to a Fainter (V=13-15) Sample

Bruce J. Hrivnak[1], Wenxian Lu[1], Gary D. Henson[2], Todd C. Hillwig[1], Ronald H. Kaitchuck[3], Brian W. Murphy[4], Justin M. Reed[1], Wesley J. Cheek[1]
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We are carrying out a long-term photometric monitoring program to study the light variability in proto-planetary nebulae (PPNe). PPNe are objects in transition between the AGB and PN phases in the evolution of low and intermediate-mass stars. These stars are often highly reddened due to their circumstellar dust and the surrounding nebulae are small and faint, imaged in scattered light with HST. Observations of the brighter ones (8-12 mag) show that they all vary in brightness. Those with F-G spectral types are found to have periods ranging from about 35 to 160 days (Hrivnak et al. 2010; Arkhipova et al. 2010, 2011), while those with hotter, early-B spectral types have short-term variations of a few days or less (Arkhipova et al. 2006). We are extending this study to fainter PPNe (13-15 mag), using observations from the Valparaiso University Observatory together with those from the SARA-North (KPNO) and SARA-South (CTIO) telescopes. Challenges exist in combining these different data sets, especially for such red stars, but nevertheless, good light curves have been obtained. Here we present the light curves and period analyses of a dozen such PPNe. Periods are found for many of these, and they are in agreement with the above ranges. These will be discussed and compared with the brighter PPN sample with respect to periods and amplitudes. This work is supported by a grant from the National Science Foundation (AST 1009974), with additional student support from the Indiana Space Grant Consortium.

156.24 – Time Series Photometry on Different Scales at the BYU West Mountain Observatory

Michael D. Joner[1]
1. Brigham Young Univ., Provo, UT, United States.

We present multiple examples of differential time series photometry using the 0.9-meter telescope located at the Brigham Young University West Mountain Observatory. The observations include monitoring of a supernova and an AGN over a period of more than 100 days. An extragalactic Cepheid that was observed nightly for two months has also been included as an example in this summary. Finally, we report on target of opportunity observations secured on objects such as delta Scuti stars, eclipsing binaries, and candidate planetary transit stars. The West Mountain Observatory operates using student and faculty observers who participate in several monitoring projects that are scheduled during each observing season in addition to their own primary program. This model has given student observers an opportunity to gain useful experience on a wide variety of different monitoring projects involving carefully timed and executed photometric observations. These observations have proven especially valuable for both observatory support and student training during the May through August portion of the observing season when most regular classes are not a competing activity. Despite the use of a considerable number of different observers at many stages of training, most of the various programs undertaken at the observatory have been successfully completed over the past five years. We wish to thank the Brigham Young University College of Physical and Mathematical Sciences as well as the Department of Physics and Astronomy for their continued support of the research activities at the West Mountain Observatory.

156.25 – Photometric Evidence of Changes in Pulsation Characteristics of Hot Subdwarf B Stars

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Rapidly pulsating subdwarf B stars (sdBVR stars) are the fastest pulsating star class in the Universe, exhibiting pulsations in light energy ranging from 80 to 600 seconds. These rare stars are especially important because the multiple pulsation frequencies found in them provide astronomers with the remarkable opportunity to research the internal structures of stars through asteroseismology. Until now, only about 70 sdBVR's have been identified and a number of these have never been re-observed after their discoveries to look for any differences in their pulsation characteristics. This study thoroughly examines changes in the pulsation characteristics of 8 of the 70 sdBVR stars. Thousands of images were processed, Fourier

transforms of light curves were calculated, and multiple noise-accounting procedures were undertaken. After analysis, it was found that the observational evidence substantiated the theory that amplitude changes occur in most sdBVR's, with 6 out of the 8 stars showing significant amplitude changes with time. Thus, a current compilation of changes on a variety of timescales, essential for further research, was documented in this study.

156.26 – High-cadence high-resolution spectroscopy of the prototype RR Lyrae

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Contributing teams: Zoey Bergstrom, Robert L. Kurucz, Thomas G. Barnes, Luca Fossati

RR Lyrae stars play an important role in astrophysics as standard candles and tracers of galactic history, but several aspects of their pulsation remain mysterious. RR Lyr, the prototype of the class, has been studied for over a century. Recently, it was observed in high (1-minute) cadence by the Kepler spacecraft, revealing several new features of its pulsation. We present a set of high-cadence, high-resolution spectra that were obtained simultaneously with the short-cadence photometry in the star and that allow us to study the star's photospheric dynamics in detail.

157 – White Dwarfs

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

157.01 – Effect of Radial Grain Settling on the Infrared Emission from White Dwarf Circumstellar Disks: An application to G29-38 and GD 56

Jean Dupuis[1], Hugh Podmore[2]
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Circumstellar debris disks around white dwarf stars have been studied extensively using a simple model of a geometrically thin, optically thick disk that is absorbing light from the central star and re-radiating in the infrared. It has been established from observations of silicate emission features that these disks are constituted of micron-sized dust grains that radiate light inefficiently. We find that there may be a relationship between grain size and orbital height; specifically we theorize that smaller, inefficiently radiating grains will be found at greater distances from the central star than larger, cooler grains. We discuss the physical motivations for this relationship and argue that this structured distribution of dust grains will raise the temperature profile of the disk above previously determined levels by simpler circumstellar disk models. We use this new result to model the infrared emission from the DAZ white dwarf stars G29-38 and GD 56, both of which are known to harbor circumstellar dust; we achieve accurate fits to data taken from IRTF, 2MASS and Spitzer and show improvement over the simple disk model. For the disk around the star G 29-38 we demonstrate that unlike the simple disk our model can describe the IR excess without exceeding the accepted sublimation temperature; for the star GD 56 we show that the settled disk accurately fits to the data and that it is not possible to describe the IR excess in this system with a simple disk of any temperature.

157.02 – A Search for Relic Planetary Systems within 25 Parsecs of the Sun

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Nearby white dwarfs (WDs) can show observable signatures of dust in infrared light due to remnant asteroid belts perturbed by planets, but the frequency of such systems is not well constrained. After the Spring 2013 results of the WIRED IV survey Hoard et al. (2013, ApJ, 770, 21) of the entire local White Dwarf population, we report on a more detailed examination of the 25 parsec sample Sion et al. (2013, AJ submitted). Using archival photometry from American Association of Variable Star Observers (APASS), 2-Micron All-Sky Survey (2MASS), and Wide-field Infrared Survey Explorer (WISE) all-sky surveys and the Villanova University White Dwarf Catalog, we generated Spectral Energy Distribution (SED) plots of each of 213 targets for near-IR excesses signaling probable or known debris disk detection. Our study confirms three previously detected disks GD 362, WD 2115-560, and G29-38 with three additional detections of excesses that show promise as candidates. This work was supported in part by NSF grant AST1008845 and by an undergraduate research award from the NASA-Delaware Space Grant Consortium.

157.03 – Dynamical Masses of Cool White Dwarfs in Double-Degenerate Visual Binaries

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The cool white dwarfs (WDs) WD 1639+153 and WD 1818+126 were originally resolved into close visual binaries containing two WDs each during a survey with the Hubble Space Telescope (HST) and its Fine Guidance Sensors (FGS). Follow up FGS observations of these two double-degenerate (DD) systems, along with the previously known DD G 107-70, have yielded the orbital elements of all three visual binaries. We find orbital periods of 3.88 yr, 12.19 yr, and 18.84 yr for WD 1639+153, WD 1818+126, and G 107-70, respectively. Moreover, for each of the systems we have been observing nearby field stars with FGS1r in POS mode to determine the local inertial reference frame, from which we obtain the parallax and proper motion of the DD, along with the motion of each WD about its system barycenter. This leads directly to a dynamical mass for each WD. We have also used HST STIS observations to obtain individual spectra of each of the six WDs, which provide the effective temperature and subclass of each WD. This provides insight into the cooling age of each star. From the cooling ages and dynamical masses, we obtain constraints on the initial-mass/final-mass relation for WD stars.

157.04 – COS UV Spectroscopy of Pulsating DB White Dwarfs

Judith L. Provencal[1, 2], Atsuko Nitta[3], Harry L. Shipman[1], James Dalessio[1], Mike Montgomery[4], Susan E. Thompson[1]
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Convection is an important energy transfer process for most stars. Yet convection is poorly understood, and remains one of the largest sources of theoretical uncertainty in stellar modeling. Pulsating white dwarfs are the ideal laboratories to provide to a self consistent description of convection in different environments. We can combine asteroseismology with nonlinear analysis of pulsating white dwarf light curves to provide empirical descriptions of convection across the hydrogen and helium instability strips. However, our ability to interpret the convection turnover timescale and its dependence on effective temperature across the helium white dwarf instability strip is severely limited by the large errors associated with optical spectroscopic temperature determinations for these objects. We present preliminary analysis of COS observations of a sample of pulsating DB white dwarfs. These observations will determine the slope of their energy distributions and determine the presence of trace abundances of H, C, O, and Si, leading to greatly improved effective temperature determinations for these stars.

157.05 – High-Resolution EUV Spectroscopy of White Dwarfs

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We compare results of high-resolution EUV spectroscopic measurements of the isolated white dwarf G191-B2B and the binary system Feige 24 obtained with the J-PEX (Joint Plasmadynamic Experiment), which was sponsored jointly by the U.S. Naval Research Laboratory and NASA. J-PEX delivers the world's highest resolution in EUV and does so at high effective area (e.g., more effective area in a sounding rocket than is available with Chandra at adjacent energies, but in a waveband Chandra cannot reach). The capability J-PEX represents is applicable to the astrophysics of hot plasmas in stellar coronae, white dwarfs and the ISM. G191-B2B and Feige 24 are quite distinct hot white dwarf systems having in common that they are bright in the portion of the EUV where He emission features and edges occur, hence they can be exploited to probe both the stellar atmosphere and the ISM, separating those components by model-fitting that sums over all relevant (He) spectral features in the band. There is evidence from these fits that atmospheric He is being detected but the result is more conservatively cast as a pair of upper limits. We discuss how longer duration satellite observations with the same instrumentation could increase exposure to detect atmospheric He in these and other nearby hot white dwarfs.

157.06 – Deep Observations of the Open Cluster NGC 6253

Elizabeth Jeffery[1]
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We have obtained deep observations of the metal rich open cluster NGC 6253 with GMOS on the Gemini-South telescope, with the goal of observing the cluster white dwarfs for the first time. These observations are an important piece and further test of the variously proposed scenarios to explain the formation of the strange white dwarfs of the metal rich cluster open NGC 6791. We will use the new observations of NGC 6253 to measure a white dwarf age and search for any anomalies in the white dwarf luminosity function. The high metallicity of this cluster will allow us to explore and better understand the formation of white dwarfs in such a high metallicity environment. These observations are an important piece in the continuing puzzle that has important implications on mass loss, white dwarf cooling, and stellar evolution as a whole.

158 – The Sun Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

158.01 – A Combined Study of Photospheric Magnetic and Current Helicities and Subsurface Kinetic Helicities of Solar Active Regions during 2006-2012

Darryl Seligman[1], Gordon Petrie[1], Rudolph Komm[1]
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We compare the average photospheric current helicity H_c, photospheric twist parameter α (a well-known proxy for the full relative magnetic helicity), and subsurface kinetic helicity K_h for 128 active regions observed between 2006-2012. We use 1436 Hinode photospheric vector magnetograms and subsurface fluid velocity data from GONG Dopplergrams. We find a significant hemispheric bias in all three parameters. The K_h parameter is preferentially positive/negative in the southern/northern hemisphere. The H_c and α parameters have the same bias for strong fields $|{\bf B}|>1000$~G). We examine the temporal variability of each parameter for each active region and identify a significant subset of regions whose three helicity parameters all exhibit clear increasing or decreasing trends. The temporal profiles of these regions have the same bias: positive/negative helicity in the northern/southern hemisphere. The results are consistent with Longcope et al.'s Σ-effect. This work is carried out through the National Solar Observatory Research Experiences for Undergraduate (REU) site program, which is co-funded by the Department of Defense in partnership with the NSF REU Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

158.02 – Kinematics of Waves in the Solar Corona: Analyzing Potential Shock Waves to Predict Solar Energetic Particle Fluxes in Space Weather

Michael Hammer[1,2], Kamen A. Kozarev[2], Kelly E. Korreck[2]
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Shock waves associated with coronal mass ejections (CMEs) are known to be one of two major sources of large solar energetic particle (SEP) events responsible for instigating dangerous space weather that can damage satellites and put the health of astronauts in space at risk. In particular, shocks in the solar corona have been shown to produce large fluxes of SEPs, each of which has energy above 10 MeV, in just minutes. We conducted a thorough search for off-limb shock wave candidate events in the solar corona from January 2011 to June 2013 as well as a kinematic analysis of these events. We are interested in studying these shock waves so that we can better predict when large SEP events will occur. To identify shock wave candidates, we used the data catalogs from the Atmosphere Imaging Assembly (AIA), which provided a 12-second high cadence necessary to produce more data on each individual wave and also make it possible to distinguish waves from other events. We searched only for off-limb events, as their profiles and radial propagation are easier to analyze. In 30 months of data, we identified 15 candidate events, 7 of which were associated with Type II radio bursts – one of the better indicators that a candidate event is a shock wave. We present the wave morphology and kinematics for these events.

158.03 – The Use of ACE Electron, Proton, and Alpha Monitor (EPAM) Data in Severe Geomagnetic Storm Forecasting

Victoria Strait[1,2], William Murtagh[2], Robert Rutledge[2]
1. Furman University, Greenville, SC, United States. 2. NOAA/SWPC, Boulder, CO, United States.

Recent research, in both the science and engineering communities, indicates that an extreme geomagnetic disturbance (GMD) could result in a profound impact on national critical infrastructure, especially the electric power grid. In response, the Federal Energy Regulatory Commission (FERC) made a ruling in May 2013 which mandates development of reliability standards that address the impact of GMDs on the electric power grid. In part, the ruling requires owners and operators of the Bulk-Power System to develop and implement operational procedures to mitigate GMD effects. Early warning of severe GMDs is paramount in these operational procedures. NOAA's space weather forecasters are responsible for GMD warnings to support the continuous and reliable operation of the nation's Bulk-Power System. NOAA forecasters rely on L1 libration point solar wind observations for CME detection and short-term, high-confidence, warnings of a GMD. This provides typically 15-45 minutes of lead-time to the onset of the storm. However, enhancements in the energetic ion measurements on the Electron, Proton, and Alpha Monitor (EPAM) instrument on the NASA ACE spacecraft have proven to be a valuable indicator of geomagnetic storm intensity, minutes and sometimes hours before the shock arrives at L1. This relationship between energetic ion enhancements (EIEs) and large geomagnetic storms was established by Smith et al. [Smith, Z., Murtagh, W., Smithtro, C. Relationship between solar wind low-energy energetic ion enhancements and large geomagnetic storms. J. Geophys. Res. 109, A01110, 2004. doi:10.1029/ 2003JA010044]. They found an excellent correlation between storms with Kp7 and the peak flux of large energetic ion enhancements. Their research was confined to the rise and maximum of Solar Cycle 23 (1998–2001) and a forecasting technique was developed and tested on that time period. We extend this research to cover the remaining years of Solar Cycle 23 (2002-2008) and the rise phase of Cycle 24 (2008-2013) to assess performance of

the technique over a full solar cycle. We also explore the relationship of EIEs measured on the EPAM 47–65 keV channel and GMDs as measured by other storm geomagnetic storm indices, e.g., Ap.

158.04 – Atmospheric Effects on Cosmic Ray Air Showers Observed with HAWC

Steven Young[1]
1. University of Wisconsin - Madison, Madison, WI, United States.

The High Altitude Water Cherenkov Gamma Ray detector (HAWC), currently under construction on the Sierra Negra volcano near Puebla, Mexico, can be used to study solar physics with its scaler data acquisition system. Increases in the scaler rates are used to observe GeV cosmic rays from solar flares while decreases in the rates show the heliospheric disturbances associated with coronal mass ejections. However, weather conditions and height-dependent state variables such as pressure and temperature affect the production of extensive particle air showers that can be detected by the scaler system. To see if these atmospheric effects can be removed, we obtained local weather data from the Global Data Assimilation System (GDAS) and the local weather station at HAWC. The scaler pulse rates were then correlated to the pressure and temperature. We present data from a Forbush decrease observed by HAWC following a significant coronal mass ejection in April 2013, and describe our efforts to remove atmospheric variations from the scaler counts. This work was partially supported by the National Science Foundation's REU program through NSF Award AST-1004881 to the University of Wisconsin-Madison.

158.05 – Variation of the Diameter of the Sun as Measured by the Solar Disk Sextant (SDS)

Terrence Girard[1], Sabatino Sofia[1], Ulysses J. Sofia[2], Laurence W. Twigg[3], William Heaps[3], Gerard Thuillier[4]
1. Yale Univ., New Haven, CT, United States. 2. American University, Washington, DC, United States. 3. NASA/GSFC, Greenbelt, MD, United States. 4. LATMOS-CNRS, Guyancourt, France.

The balloon-borne Solar Disk Sextant (SDS) experiment has measured the angular size of the Sun on seven occasions spanning the years 1992 to 2011. The solar half-diameter -- observed in a 100-nm wide passband centered at 615 nm -- is found to vary over that period by up to 200 mas, while the typical estimated uncertainty of each measure is 20 mas. The diameter variation is not in phase with the solar activity cycle; thus, the measured diameter variation cannot be explained as an observational artifact of surface activity. Other possible instrument-related explanations for the observed variation are considered and found unlikely, leading us to conclude that the variation is real. The SDS and its results are presented here, including the analysis procedure necessary to calibrate the instrument and allow comparison of diameter measures across decades.

158.06 – Recent VLA Observations of Coronal Faraday Rotation

Jason E. Kooi[1], Patrick D. Fischer[1], Jacob J. Buffo[1], Steven R. Spangler[1]
1. University of Iowa, Iowa City, IA, United States.

Proposed mechanisms for coronal heating and acceleration of the fast solar wind, such as Joule heating by coronal currents or dissipation of Alfvén waves, depend on the magnetic field structure and plasma characteristics of the corona within heliocentric distances of 5 solar radii. Faraday rotation observations can provide unique information on the magnetic field in this region of the corona. We report on sensitive full-polarization observations of the radio galaxy 3C228 through the solar corona at heliocentric distances of 4.6 – 5.0 solar radii. The observations were made with the VLA in August of 2011. We performed these observations at 5.0 and 6.1 GHz (each with a bandwidth of 128 MHz), permitting measurements deeper in the corona than previous VLA observations at 1.4 and 1.7 GHz. While the measured Faraday rotation was lower than our a priori expectations, we can understand the magnitude of the observed Faraday rotation in terms of observed properties of the corona on the day of observation. For coronal remote sensing, an advantage of using extended extragalactic radio sources such as 3C228 is that such observations provide multiple lines of sight through the corona. Our data provide two lines of sight (separated by 46?, 33,000 km in the corona), one to a northern hotspot and the other to a southern hotspot with fractional polarizations of 14% and 8% respectively. We detected three periods over the eight-hour observing session during which there appeared to be a difference in the Faraday rotation between these two closely spaced lines of sight. These measurements yield an estimate of 2 – 4 GA for coronal currents. We did not directly detect rotation measure fluctuations. Our data impose upper limits on rotation measure fluctuations caused by coronal waves. The observed upper limits were 3.3 and 6.4 rad/m^2 and are comparable to and not inconsistent with some models for Alfvén wave heating. This research was supported at the University of Iowa by grants ATM09-56901 and AST09-07911 from the National Science Foundation.

158.07 – Annual solar motion and spy satellites

Margaret Jensen[1], Shane L. Larson[1]
1. Utah State University, Logan, UT, United States.

A topic often taught in introductory astronomy courses is the changing position of the Sun in the sky as a function of time of day and season. The relevance and importance of this motion is explained in the context of seasons and the impact it has on human activities such as agriculture. The geometry of the observed motion in the sky is usually reduced to graphical representations and visualizations that can be difficult to render and grasp. Sometimes students are asked to observe the Sun's changing motion and record their data, but this is a long-term project requiring several months to complete. This poster outlines an activity for introductory astronomy students that takes a modern approach to this topic, namely determining the Sun's location in the sky on a given date through the analysis of satellite photography of the Earth.

158.08 – Two-dimensional Hydrodynamic Simulations of Angular Momentum Balance and Meridional Circulation in the Solar Convective Zone, Using a Viscoelastic Model for the Turbulent Maxwell Stresses due to Magnetoconvection

Peter T. Williams[1]

1. Agilent Technologies, Santa Clara, CA, United States.

The solar rotation profile both at the photosphere and within the solar convective zone (SCZ) and tachocline is now well-known. Physically, it determines and is determined by both the meridional circulation and the internal stress tensor in the SCZ. One of the contributions to the stress in the SCZ is the turbulent, tangled magnetic field due to magnetoconvection. In previous work we have discussed a viscoelastic model for the stress tensor. This viscoelastic model attempts to recover the stress due to the sub-integral scale magnetic field. We have argued that the inclusion of such a model in simulations could have a significant effect on the predicted meridional circulation of the SCZ, and therefore also the predicted angular momentum balance and solar rotation profile. Here we present for the first time the numerical results of a hydrodynamic simulation of the SCZ including our viscoelastic model for the turbulent Maxwell stress. Depending on choice of parameters, these stresses can contribute to a forcing of the meridional circulation that is clockwise (CW) in the usual notation, which tends to distribute angular momentum more in keeping with observations. We argue that including viscoelastic terms in the prescription for the stress tensor may offer an improved method of predicting the angular momentum balance and meridional circulation in the SCZ when performing 2D simulations.

158.09 – Design and Construction of a Solar Observatory in a Liberal Arts Environment: Austin College's Gnomon and Meridian Line

David D. Baker[1], Donald Salisbury[1]

1. Austin College, Sherman, TX, United States.

Austin College's indoor solar observatory is one of the most distinctive features in its new IDEA Center science building. Patterned after 16th and 17th century solar observatories in European cathedrals, the IDEA Center solar facility will be used extensively for public events, introductory astronomy courses, and reproductions of important historical scientific measurements. A circular aperture, or gnomon hole, on the roof with diameter 32 mm allows a beam of sunlight to trace a path across the atrium floor 15.37 meters below. At local solar noon, the Sun's image falls directly on a brass meridian line. Special markers for solstices and equinoxes highlight western, eastern, and indigenous cultural contributions to astronomy: Macedonian symbol of the Sun marks summer solstice, Chinese Sun symbol showcases the equinoxes, and the Mayan symbol of the Sun celebrates winter solstice. The location directly beneath the gnomon hole is marked by the universal scientific symbol of the Sun. Direct solar measurements and mathematical models were used in design and implementation of the meridian line. During IDEA Center building construction in Fall 2012, undergraduate students measured the Sun's position at various times. The finished floor was set in February 2013, well before a full year's worth of measurements could be recorded. A mathematical model including the effects of aperture size and atmospheric refraction was needed to predict the size and location of the Sun on the meridian line throughout the year. Confirmation of the meridian line occurred on Summer Solstice 2013 when the Sun's image precisely hit the Macedonian marker at the correct time.

158.10 – A Search for Flare Related Systematic Changes in Stokes V Asymmetries in NOAA 11429

Tyler Sinotte[1, 2], Brian Harker[1]

1. National Solar Observatory, Tucson, AZ, United States. 2. University of Wisconsin-Madison, Madison, WI, United States.

While Stokes V profiles in a static local thermodynamic equilibrium (LTE) atmosphere are perfectly anti-symmetric about the zero-crossing wavelength, this is rarely the case in observed solar Stokes V profiles. Not only do these profiles show asymmetries, but many also have complex profiles including profiles with three or more lobes, profiles with multiple peaks per lobe, and profiles with only a single lobe. These asymmetries can be measured through both the area under the profile as well as the amplitude of their peaks. Because the asymmetries are affected by the magnetic field present in the Sun, they are most often seen in active regions within the Sun and can provide information about the gradients of the magnetic field and plasmas velocity along the observer's line of sight. Flaring regions are of particular interest due to the intense magnetic fields and release of magnetic energy associated with these events. The Synoptic Optical Long-term Investigations of the Sun

(SOLIS) Vector Spectromagnetrograph (VSM), operated by the National Solar Observatory (NSO), collected a time series of Stokes polarization profiles around the FeI λ6301.5 and FeI λ6302.5 lines within the flaring region of NOAA 11429 from 17:03 UT to 18:06 UT on March 13th, 2012. Since the asymmetries in the Stokes V profiles can provide information about the magnetic field gradient, we searched for systematic changes within the flaring region of NOAA 11429.

158.11 – Predicting Ground Illuminance

Michael V. Lesniak[1]
1. U.S. Naval Observatory, Washington, DC, United States.

Our Sun outputs 3.85×10^{26} W of radiation, of which ?37% is in the visible band. It is directly responsible for nearly all natural illuminance experienced on Earth's surface, either in the form of direct/refracted sunlight or in reflected light bouncing off the surfaces and/or atmospheres of our Moon and the visible planets. Ground illuminance, defined as the amount of visible light intercepting a unit area of surface (from all incident angles), varies over 7 orders of magnitude from day to night. It is highly dependent on well-modeled factors such as the relative positions of the Sun, Earth, and Moon. It is also dependent on less predictable factors such as local atmospheric conditions and weather. Several models have been proposed to predict ground illuminance, including Brown (1952) and Shapiro (1982, 1987). The Brown model is a set of empirical data collected from observation points around the world that has been reduced to a smooth fit of illuminance against a single variable, solar altitude. It provides limited applicability to the Moon and for cloudy conditions via multiplicative reduction factors. The Shapiro model is a theoretical model that treats the atmosphere as a three layer system of light reflectance and transmittance. It has different sets of reflectance and transmittance coefficients for various cloud types. Ground illuminance data from an observing run at the White Sands missile range were obtained from the United Kingdom Meteorology Office. Based on available weather reports, five days of clear sky observations were selected. These data are compared to the predictions of the two models. We find that neither of the models provide an accurate treatment during twilight conditions when the Sun is at or a few degrees below the horizon. When the Sun is above the horizon, the Shapiro model straddles the observed data, ranging between 90% and 120% of the recorded illuminance. During the same times, the Brown model is between 70% and 90% of the observed value. While the results are preliminary, the Shapiro model appears to have better predictive power than does the Brown model.

160 – Developing Our Own Future: Undergraduate Research and Enrichment Through Peer-Led Programs Poster Session

Poster Session – Exhibit Hall ABC – 06 Jan 2014 09:00 am to 06:30 pm

160.01 – How to Make a Club from Scratch: The Beginning of the University of Arizona Astronomy Club

Amy Robertson[1], Kevin Hardegree-Ullman[2], Allison P. Towner[1], Amanda Walker-LaFollette[1], Timothy Carleton[3], Donald W. McCarthy[1]
1. University of Arizona, Tucson, AZ, United States. 2. University of Toledo, Toledo, OH, United States. 3. University of California, Irvine, Irvine, CA, United States.

Beginning and maintaining an independent, student run club can be a challenge. The University of Arizona Astronomy Club has been working hard to build a strong basis since its revitalization in 2007. Since that time, the club has evolved and learned strategies for increasing and maintaining membership through research, community outreach, fund raising, telescope building projects and educational scale models. We will discuss how club involvement benefits astronomy and non-astronomy majors, the University, the astronomical community and the local community through social support and networking.

160.02 – Undergraduate Skills Laboratories at Sonoma State University

Amandeep Gill[1], Kevin Zack[1], Hunter Mills[1], Ben Cunningham[1], Stephan Jackowski[1]
1. Sonoma State University, Rohnert Park, CA, United States.

Due to the current economic climate, funding sources for many laboratory courses have been cut from university budgets. However, it is still necessary for undergraduates to master laboratory skills to be prepared and competitive applicants when entering the professional world and/or graduate school. In this context, student-led programs may be able to compensate for this lack of formal instruction and reinforce concepts from lecture by applying research techniques to develop hands-on comprehension. The Sonoma State University Chapter of Society of Physics Students has established a peer-led skills lab to teach research techniques in the fields of astronomy and physics. The goal is to alleviate the pressures of both independently learning and efficiently applying techniques to junior and senior-level research projects. These skill labs are especially valuable for nontraditional students who, due to work or family duties, may not get a chance to fully commit to research projects. For example, a topic such as Arduino programming has a multitude of applications in both astronomy and physics, but is not taught in traditional university courses. Although some programming and electronics skills are taught in (separate) classes, they are usually not applied to actual research projects, which combined expertise is needed. For example, in astronomy, there are many situations involving programming telescopes and taking data with electronic cameras. Often students will carry out research using these tools but when something goes wrong, the students will not have the skills to trouble shoot and fix the system. Another astronomical topic to be taught in the skills labs is the analysis of astronomical data, including running remote telescopes, analyzing photometric variability, and understanding the concepts of star magnitudes, flat fields, and biases. These workshops provide a setting in which the student teacher may strengthen his or her understanding of the topic by presenting it to peers. Students teaching fellow peers is an ideal method of furthering understanding for all participants, and the skills lab established by the SPS has begun this process at SSU.

160.03 – The Cornell Astronomical Society: The Student Experience of Running an Observatory

Michael Hammer[1], Brecken Blackburn[1], Jeremy Fredricks[1], Kelly Garcia[1], Adrian Poniatowski[1], Kevin Schindler[1], Arthur Wilk[1]
1. Cornell University, Ithaca, NY, United States.

The Cornell Astronomical Society is an undergraduate student-run organization that operates Cornell's on-campus Fuertes Observatory with the help of members of the astronomy department and local amateur astronomy volunteers. While some of our members study physics or astronomy, the majority of our club members represent a diverse spectrum of majors both inside and outside of other STEM fields. Our primary activity as a club is to host weekly public stargazing nights that are attended annually by over two thousand people in a city of Ithaca that has a population of only one hundred thousand. We train our members to use a variety of telescopes and to open and close the observatory with the ultimate goal of having any one of us able to operate Fuertes individually. We also teach stargazing-related astronomy knowledge and host a weekly public lecture series, in which CAS members give talks on basic, but interesting topics in astronomy. Our club effort has made Fuertes Observatory a true part of the Cornell experience.

160.04 – Bridging the gap between Undergrads and Grads: The mentor next door

Aaron White[1]
1. San Francisco State University, San Francisco, CA, United States.
Contributing teams: Aaron Gruberg

Astronomy undergraduates must adapt to countless changes both in work and life as they transition into upper division students. Besides managing a larger, more involved workload, they must begin preparing for their future with things like the Physics GRE, applications for graduate schools, conference attendance/preparation, or finding jobs outside of academia. These experiences come very rapidly, and often without warning, leaving students in a constant uphill struggle, unsure of what challenges lie before them, many of which they may not have even heard of yet. Graduate students have been through all of these experiences only a few years prior, giving them great potential for mentorship, informing undergrads of exactly what challenges lie ahead, and the best ways to prepare and meet them. These exchanges are disappointingly uncommon though, as direct interaction between upper division undergrads and grads is often fleeting, if not unheard of outside of student/TA relationships. This unspoken barrier between undergrads and grads can leave students studying and working just doors apart, yet never meeting, barring them from taking advantage of the invaluable exchanges they could be participating in. We will describe how the terminal masters program at San Francisco State has helped create a unique environment which has largely broken this divide between undergrads and grads, allowing for incredible mentorship as well as collaboration and exchange of ideas from both sides. We offer advice for building these relationships between astronomy students of any kind, giving suggestions undergrads, grads, or faculty can aim for to help forge these relationships. The poster portion of this presentation will focus on techniques graduate students can employ for developing relationships with, and becoming successful mentors to undergrads, as well as the advantages and experience they gain by doing so.

160.05 – Astronomy at the Market

Robert Roten[1], Anca Constantin[1], Emil Christensen[1], Emily Dick[1], Josiah Lapolla[1], Andrew Nutter[1], James Corcoran[1], Nathan DiDomenico[1], Brandon Kyle Eskridge[2, 1], Anthony Saikin[3, 1]
1. James Madison University, Harrisonburg, VA, United States. 2. College of William and Mary, Williamsburg, VA, United States. 3. University of New Hampshire, Durham, NH, United States.

We present here an energetic grass-roots outreach program run entirely by undergraduate physics and astronomy majors at James Madison University. Our "Team Awestronomy" takes Astronomy out to the Market, literally. Once a month, for eight months during the academic year, the group sets up a "scientific corner" at the Harrisonburg Farmers Market, offering people the chance to meet with astrophysicists (in the making) and discuss science. Our group members wear t-shirts with simple messages like "Ask me about the Sun," "...about Black Holes and Mega-Masers" or "...about Big Bang" that initiate the dialog. We help our audience with observations of solar activity through our department's Coronado telescope equipped with a safe H-alpha filter, sunspotters, and the incredibly simple yet durable and accurate handheld (Project Star) spectrometers, and invite them to the free Saturday Planetarium shows and the star parties hosted by our department on the JMU campus. The team is also prepared with a suite of fun activities aimed particularly at K-5 kids, e.g., building (and eating, after investigating out-gassing properties of) "dirty comets," making craters (in pans with flour or sand) and testing how different types of impactors (pebbles, ping-pong balls or even crumpled aluminum foil) affect crater formation, and demonstrations of shock wave created in supernova explosions. The main goals of this outreach program are: 1) to illustrate to people of all ages that science is a fun, creative, and exciting process; 2) to empower people to be curious and to ask questions; 3) to demonstrate that science is a viable career path chosen by many diverse individuals; and 4) to nurture a sense of wonder and awe for the Universe. While this outreach program is aimed at a very general audience, of an extremely wide range, we expect to produce a significant impact on K-12 students in general and in particular on the home-schooled kids. There is a relatively high fraction (~20%) of home-schooled children in Harrisonburg/Rockingham County. We present a variety of methods by which we assess the success and impact of this program to the community.

160.06 – Albion's Astronomy Club--A Community of Many Faces

Alysandra Ganem[1], Carlos Matti[1], Lindsay Ciastko[1], Nicolle Zellner[1]
1. Albion College, Albion, MI, United States.

The Albion College Astronomy Club has a bright and rich history, and an even more luminous future. The club has always been and continues to be rooted in educating club members, fellow undergraduates and the community about astronomy. Public observing events are held several times each year, with the support of physics faculty and astronomy club members. In the spring of 2013, the club built and launched its first model rocket. The building of rockets has expanded club membership, which will ensure the continuity of our astronomy club. Additionally, in the 2013-2014 academic year, we plan to work with the local science museum to educate after-school groups about constellations and how much fun can be had observing, sans telescope. All of these activities culminate into a club that is integrative and educationally enriching.

160.07 – The League of Astronomers: Outreach

Anthony Paat[1], Andrew Brandel[1], Denise Schmitz[1], Ramon Sharma[1], Nancy H. Thomas[1], Juan

Trujillo[1], Christopher S. Laws[1]
1. University of Washington, Seattle, WA, United States.
Contributing teams: League of Astronomers

The University of Washington League of Astronomers (LOA) is an organization comprised of University of Washington (UW) undergraduate students. Our main goal is to share our interest in astronomy with the UW community and with the general public. The LOA hosts star parties on the UW campus and collaborates with the Seattle Astronomical Society (SAS) on larger Seattle-area star parties. At the star parties, we strive to teach our local community about what they can view in our night sky. LOA members share knowledge of how to locate constellations and use a star wheel. The relationship the LOA has with members of SAS increases both the number of events and people we are able to reach. Since the cloudy skies of the Northwest prevent winter star parties, we therefore focus our outreach on the UW Mobile Planetarium, an inflatable dome system utilizing Microsoft's WorldWide Telescope (WWT) software. The mobile planetarium brings astronomy into the classrooms of schools unable to travel to the UW on-campus planetarium. Members of the LOA volunteer their time towards this project and we make up the majority of the Mobile Planetarium volunteers. Our outreach efforts allow us to connect with the community and enhance our own knowledge of astronomy.

160.08 – Undergraduate Research in the University of Arizona Astronomy Club

Ian Cates[1], Allison P. Towner[1], Amanda Walker-LaFollette[1], Jake Turner[2], Kevin Hardegree-Ullman[3], Kyle Pearson[1]
1. University of Arizona, Tucson, AZ, United States. 2. University of Virginia, Charlottesville, VA, United States. 3. University of Toledo, Toledo, OH, United States.

Participation in research as an undergraduate is an invaluable learning experience that leads to successful post-undergrad studies. Because of this, the University of Arizona Astronomy Club strives to provide multiple opportunities for its members to get involved in research as early as possible. Areas of research covered by our projects include exoplanet research, stellar cycles, and radio observations. These projects cover exoplanet parameterization, the utilization of Kepler data, and various star-formation studies, respectively. Participation in our projects builds stronger data-collecting and reduction skills, while also leading to tangible achievements such poster presentations at AAS, ASP, and DPS, and published papers in astronomical journals.

160.09 – Outreach and Astronomy-Education Activities of the University of Arizona Astronomy Club

Allison M. McGraw[1], Kevin Hardegree-Ullman[2], Amanda Walker-LaFollette[1], Allison P. Towner[1]
1. The University of Arizona, Tucson, AZ, United States. 2. The University of Toledo, Toledo, OH, United States.

The University of Arizona Astronomy Club provides unique outreach experiences for all ages. Our undergraduates work together to volunteer their time for various types of outreach events. This club uses several techniques to execute astronomy education such as hands-on 3D models, exciting demonstrations of scientific phenomena, and multiple small telescopes for both solar and night-time viewing. The students bring the models and telescopes to locations both on and off campus; from dark sky locations in the desert southwest to elementary schools, our undergraduates are willing to teach astronomy just about anywhere.

160.10 – Mizzou Student Astronomical Society – benefiting everyone

Jason Briggs[1], Angela Speck[1], Lanika Ruzhitskaya[1]
1. University of Missouri, Columbia, MO, United States.

At the University of Missouri (Mizzou), astronomy oriented students are Physics majors taking an "emphasis" in astronomy. However, student organizations such as the Mizzou Student Astronomical Society (SAS) are beneficial to not only the physics and non-physics students, but also to the general. For physics student, SAS allows a learning experience that is not offered in any class. This learning experience involves preparing and performing scientific speeches, and organizing public outreach projects. This unique learning experience helps the physics student become more confident, influential, and knowledgeable with the information they learn in their studies. Physics students are given an opportunity to write and give talks to non-physics students, which helps with practicing to communicate scientific ideas in an easy to understand format. Writing and performing these speeches also helps the physics student to retain their knowledge by reinforcing information through teaching. When a talk is done well, meaning it is easy for the audience to understand and retain, then the physics student also has the unique experience of being influential by invoking an interest in astronomy and science as a whole. We will present Mizzou SAS's activities and how they benefit physics and non-physics students as well as the general public.

160.11 – Revealing the Universe to Our Community: NMSU's Society of Astronomy

Students' Dedication to Public Outreach

Mercedes Maldonado[1], Shannon Rees[1], Amber Medina[1], Dana Beasley[1], Angelica Campos[1], Nancy J. Chanover[1], Kyle Uckert[1], Jean McKeever[1]
1. New Mexico State University, Las Cruces, NM, United States.

The New Mexico State University (NMSU) Society of Astronomy Students (SAS) is an undergraduate organization centered on students' passions for learning and sharing knowledge about the field of astronomy. The SAS strives to become one of the most active clubs on the NMSU campus by their involvement in both astronomy and non-astronomy related public outreach and community service events. NMSU is located in Las Cruces, NM, where Clyde Tombaugh made great contributions both to the field of astronomy and to our local community. He was able to spark the community's interest in astronomy and science in general; this is an aspect of his career that the SAS strives to emulate. To do this, the SAS participates in community outreach events with the goal of stimulating curiosity and providing opportunities for the public to observe and understand exciting phenomenon occurring in our universe. With help from the NMSU Astronomy Department, the SAS is able to volunteer alongside the Astronomy Graduate Student Organization (AGSO) at events for people of all ages. Working jointly with the AGSO allows us to be mentored by the very students who were in our shoes not long ago; they educate us about the wonders of the universe, just as we wish to educate the community. This provides an enlightening and enriching environment for both club and community members. The NMSU Astronomy Department hosts events for the entire community, such as observing nights held at Tombaugh Observatory — which SAS members attend and help advertise — where community members learn about and view objects in the night sky through telescopes. SAS members assist with field trips where local middle and elementary school students attend presentations and participate in astronomy-related activities on the NMSU campus. These hands-on activities are presented in an understandable way, and are meant to increase appreciation for all of the exciting subjects our universe has to offer. Other outreach events include Star Parties, which are observing events held at local schools, as well as volunteering in classrooms. These various events allow the SAS to reach their goals by becoming involved with not only the community, but also the education of students.

160.12 – Reaching Beyond The Stars

Mariah Baker[1], Lee Rosenthal[1], Andrea Gaughan[1], Erica Hopkins[1]
1. Haverford College, Haverford, PA, United States.

Strawbridge Observatory at Haverford College is home to a undergraduate-led public observing program. Our program holds ~once monthly public events throughout the academic year that take advantage of eyepiece observing on our 16-inch and 12-inch telescopes as well as of the classroom, library, and projection system. These resources allow us to organize a variety of astronomy related activities that are engaging for individuals of all ages: accessible student talks, current film screenings and even arts and crafts for the families who attend with young children. These events aim to spark curiosity in others about scientific discovery and about the remarkable nature of the world in which we live. In addition to exciting local families about astronomy, this program has excited Haverford students from a range of disciplines about both science and education. Being entirely student led means that we are able to take the initiative in planning, coordinating and running all events, fostering an atmosphere of collaboration, experimentation and commitment amongst our volunteers. Additionally, this program is one of the few at Haverford that regularly reaches beyond the campus walls to promote and build relationships with the outside community. In light of this, our program presents a distinctive and enlightening opportunity for student volunteers: we get to use our scientific backgrounds to educate a general audience, while also learning from them about how to communicate and inspire in others the excitement we feel about the subject of astronomy. The work on this project has been supported by NSF AST-1151462.

160.13 – Peer Development of Undergraduate Astronomers and Physicists at the University of Wisconsin - Madison

Melissa Abler[1]
1. Univ of Wisconsin, Madison, Madison, WI, United States.
Contributing teams: Physics Club of UW-Madison

The physics club at the University of Wisconsin – Madison is actively engaged in many peer-led activities that foster development of career-oriented skills. Peer mentoring through drop-in tutoring provides peer support to promote retention in the astronomy and physics majors, as well as developing valuable teaching and communication strategies. The physics club is also heavily involved in outreach and education through demonstrations on campus, strengthening student connections to and aiding in retention of classroom information. Public demonstrations also develop valuable communication skills which will be required as a professional. Application-oriented development of students is further enhanced by semiannual visits to research facilities in the surrounding area which provide interested students the opportunity to see non-university facilities firsthand. Close contact with faculty - a valuable resource for undergraduates - is achieved through faculty attendance at club events and presentation of faculty research to interested students. Undergraduates also have the opportunity through the physics club to speak with the weekly colloquium presenter, learning more about each presenter's experiences with graduate school, research, and career path.

102 – Cosmology & CMB I
Oral Session – Potomac Ballroom D – 06 Jan 2014 10:00 am to 11:30 am

102.01D – Toward a precise determination of the neutral gas fraction at z~7 using the Lyman alpha fraction test

Matthew A. Schenker[1], Richard S. Ellis[1], Daniel Stark[2]
1. Caltech, Pasadena, CA, United States. 2. University of Arizona, Tucson, AZ, United States.

In recent years, early star-forming galaxies have emerged as one of the most promising probes of the reionization era. A particularly valuable method is Lyman alpha fraction test, which tracks the fraction of color-selected Lyman break galaxies that show strong Lyman alpha in emission across cosmic time. Our previous work, along with several independent studies, identified a marked decline in this fraction beyond z ~ 6.5, thus providing important evidence that we may be directly observing the final stages of reionization. Yet until now, the method for inferring a neutral gas fraction from this Lyman alpha data has been rather imprecise. Earlier studies failed to take into account evolution in specific galaxy properties that may influence the visibility of Lyman alpha apart from any evolution in the intergalactic medium. These include variations in the intrinsic production of Lyman alpha and the emission line offset from the galaxy's systemic velocity. Here we present a comprehensive analysis of these factors affecting the derived neutral hydrogen fraction, and construct a predictive model for the intrinsic Lyman alpha emission taking into account galaxy luminosity, size, and most importantly, ultraviolet color. Using our improved model, we reassess the implications of the most recent data for the ionized state of the intergalactic medium at z ~ 7-8.

102.02 – Finding the First Cosmic Explosions: Hypernovae and Pair-Instability Supernovae

Brandon Wiggins[1,2], Daniel J. Whalen[2], Victor Migenes[1]
1. Brigham Young University, Provo, UT, United States. 2. Los Alamos National Laboratory, Los Alamos, NM, United States.
Contributing teams: Astrophysics Research Group at Los Alamos National Laboratory

The cosmic Dark Ages ended with the formation of the first stars at z ~ 20, or ~ 200 Myr after the Big Bang. Because they literally lie at the edge of the observable universe Pop III stars will be beyond the reach of even next generation observatories like JWST and the Thirty-Meter Telescope. But primordial supernovae could soon directly probe the properties of the first stars because they can be observed at high redshifts and their masses can be inferred from their light curves. I will present numerical simulations of Pop III hypernovae and pair-instability supernovae and their light curves done with the Los Alamos RAGE and SPECTRUM codes. We find that these two types of explosions will be visible at z ~ 10 - 15, revealing the positions of ancient dim galaxies on the sky and tracing their star formation rates.

102.03 – In Pursuit of the Thermal State of the IGM at Redshift 20: Radio Foreground Characterization

Lincoln J. Greenhill[1]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.
Contributing teams: LEDA collaboration

One of the great challenges of cosmology today is tracing the thermal history of the Universe from global reionization back to recombination. The Large Aperture Experiment to Detect the Dark Age (LEDA) will set direct constraints on sky-averaged spectral-line absorption of the Cosmic Microwave Background by neutral Hydrogen in the intergalactic medium at redshift ~ 20. Line intensity, breadth, and center frequency enable hypothesis testing for models of heating during the preceding Dark Age and the epoch at which sustained star formation began. LEDA has begun science observations at the Long Wavelength Array in Owens Valley. I will report initial characterizations of the foreground sky, effectiveness of subtraction, and assessment of how difficult or easy it may be to take the next step: measurement of the angular power spectrum of HI fluctuations just after the end of the Dark Age.

102.04D – Simulating Metal-Poor and Metal-Free Star Formation in the Earliest Galaxies

Chalence Safranek-Shrader[1]
1. University of Texas at Austin, Austin, TX, United States.

The end of the cosmic dark ages was brought about by the formation of the first stars and galaxies. Since this epoch is currently outside of observational reach, numerical studies are key in understanding this uncharted cosmic epoch. In this dissertation talk, I will describe my work using high-resolution, zoom-in simulations to understand the formation of these earliest stellar associations in a cosmological setting. The overarching focus will be on the fragmentation of collapsing gas

and how this process is moderated by the gas chemistry, radiation fields, and realistic cosmological initial conditions. A key aspect of this work has been the development of sophisticated physics modules for the hydrodynamics code FLASH, including non-equilibrium chemistry, radiative transfer schemes, and sink particles. I will begin by describing how more moderate mass Population III stars ended their lives with a relatively quick heavy-element enrichment of their host dark matter halos, resulting in prompt Population II star formation. The introduction of metals from the first supernovae is believed to induce a star formation mode transition from high to low characteristic mass. I will show how the fragmentation of such metal enriched gas depends strongly on the metallicity, with fragmentation setting in when gas hits the CMB temperature floor. If present, an H2 photo-dissociating Lyman-Werner radiation background can delay the formation of the first stars and potentially result in clustered metal-free star formation in more massive, self-shielding halos at lower redshift. I will present results from recent simulations that follow the collapse and fragmentation of the first dust enriched gas to high densities (n ~ 10^14 cm^-3), analyzing the interplay of dust cooling with a CMB temperature floor and gauging the effect that dust heating from protostellar feedback has on the outcome of star formation. Finally, I will discuss this work's implications for next-generation observatories, in particular the James Webb Space Telescope.

102.05 – 21cm Reionization Results Suggesting X-Ray Heating

Aaron Parsons[1]
1. University of California, Berkeley, Berkeley, CA, United States.
Contributing teams: PAPER, HERA

We present recent results from the Precision Array for Probing the Epoch of Reionization (PAPER) that use a novel fringe-rate filtering technique to dramatically enhance sensitivity and suppress leakage originating from off-axis polarized foregrounds. This new technique, combined with the delay-spectrum approach to foreground avoidance that is PAPER's hallmark, produces an upper limit on 21cm emission from the Epoch of Reionization (EoR) that begins to rule out physically plausible scenarios for bright reionization. We also discuss the proposed next-generation 21cm reionization instrument, HERA, that incorporates the advances spearheaded by PAPER and the MWA, and features a modified antenna element optimized for sensitivity and foreground avoidance. HERA proceeds in stages of 127, 331, and 568 elements, with each stage delivering new science capabilities that advance our understanding of reionization. HERA is optimized for characterizing the EoR power spectrum in detail, and in its final stages, will also be capable of imaging the EoR directly.

102.06 – Linear and Circular polarization of CMB and cosmic 21cm radiation

Soma De[1], Tanmay Vachaspati[1], Levon Pogosian[2], Hiroyuki Tashiro[1]
1. Arizona State University, Tempe, AZ, United States. 2. Simon Fraser University, Burnaby, BC, Canada.

I will discuss the effect of galactic and primordial magnetic field on the linear polarization of CMB. Faraday Rotation (FR) of CMB polarization, as measured through mode-coupling correlations of E and B modes, can be a promising probe of a stochastic primordial magnetic field (PMF). We use existing estimates of the Milky Way rotation measure (RM) to forecast its detectability with upcoming and future CMB experiments. We find that a realistic future sub-orbital experiment, covering a patch of the sky near the galactic poles, can detect a scale-invariant PMF of 0.1 nano-Gauss at better than 95% confidence level. Next I'll discuss how the galactic magnetic field affects polarization of 21 cm. Unpolarized 21 cm radiation acquires a certain level of linear polarization during the EoR due to Thompson scattering. This linear polarization, if measured, could probe important information about the EoR. We show that a 99 % accuracy on galactic rotation measure (RM) data is necessary to recover the initial E-mode signal. I will conclude my talk by addressing the very interesting question of if CMB can be circularly polarized due to the secondary effects along the line of sight. As the CMB passes through galaxies and galaxy clusters, which could generate a circular polarization by the method of Faraday conversion (FC) (Pacholczyk, 1998, Cooray et al, 2002). Particularly explosions of first stars can induce circular polarization (due to Faraday conversion) and it has no strong local foreground. The unique frequency dependence of FC signal will allow one to eliminate other possible sources of circular polarization enabling to probe the first star explosions.

102.07 – The effect of aberration on partial-sky measurements of the cosmic microwave background temperature power spectrum

Donghui Jeong[1], Jens Chluba[1], Liang Dai[1], Marc Kamionkowski[1], Xin Wang[1]
1. Johns Hopkins University, Baltimore, MD, United States.

Our motion relative to the cosmic-microwave-background (CMB) rest frame deflects light rays giving rise to shifts as large as L -> L(1+beta), where beta=0.00123 is our velocity (in units of the speed of light) on measurements CMB fluctuations. Here we present a novel harmonic-space approach to this CMB aberration that improves upon prior work by allowing us to (i) go to higher orders in beta, thus extending the validity of the analysis to measurements at L > 1/beta ~ 800; and (ii) treat the effects of window functions and pixelization in a more accurate and computationally efficient manner. We calculate precisely the magnitude of the systematic bias in the power spectrum inferred from the partial sky, and show that aberration shifts the multipole moment by Delta L/L ~ beta<cos(theta)>, with <cos(theta)> averaged over the survey footprint. Such a shift, if

ignored, would bias the measurement of the sound-horizon size theta_* at the 0.01%-level, which is comparable to the measurement uncertainties of Planck. The bias can then propagate into cosmological parameters such as the angular-diameter distance, Hubble parameter and dark-energy equation of state. We study the effect of aberration for current Planck, South Pole Telescope (SPT) and Atacama Cosmology Telescope (ACT) data and show that the bias cannot be neglected. We suggest that the small tension between Planck, ACT, and SPT may be due partially to aberration. An Appendix shows how the near constancy of the full-sky power spectrum under aberration follows from unitarity of the aberration kernel.

103 – Exoplanets and Kepler Astrophysics

Special Session – Potomac Ballroom A – 06 Jan 2014 10:00 am to 11:30 am

In addition, to revolutionizing our view of exoplanets, Kepler has also extended our understanding of the time domain astrophysics. The talks presented here will yield insight into the tremendous power of citizen science in the discovery of exoplanets (Meg Schwamb), will present a discussion of the stellar variability and its relationship to the stellar properties (Fabienne Bastien), and the variability of active galactic nuclei (Rick Edelsen).

103.01 – Planet Hunters: Kepler by Eye

Megan E. Schwamb[1], Chris Lintott[2, 3], Debra Fischer[4], Arfon M. Smith[3], Tabetha S. Boyajian[4], John M. Brewer[4], Matthew J. Giguere[4], Stuart Lynn[3], Michael Parrish[3], Kevin Schawinski[5], Joseph Schmitt[4], Robert Simpson[2], Ji Wang[4]
1. Institute of Astronomy & Astrophysics, Academia Sinica (ASIAA), Taipei, Taiwan. 2. University of Oxford, Oxford, United Kingdom. 3. Adler Planetarium, Chicago, IL, United States. 4. Yale University, New Haven, CT, United States. 5. ETH Zurich , Zurich, Switzerland.

Planet Hunters (http://www.planethunters.org), part of the Zooniverse's (http://www.zooniverse.org) collection of online citizen science projects, uses the World Wide Web to enlist the general public to identify transits in the pubic Kepler light curves. Planet Hunters utilizes human pattern recognition to identify planet transits that may be missed by automated detection algorithms looking for periodic events. Referred to as 'crowdsourcing' or 'citizen science', the combined assessment of many non-expert human classifiers with minimal training can often equal or best that of a trained expert and in many cases outperform the best machine-learning algorithm. Visitors to the Planet Hunters' website are presented with a randomly selected ~30-day light curve segment from one of Kepler's ~160,000 target stars and are asked to draw boxes to mark the locations of visible transits in the web interface. 5-10 classifiers review each 30-day light curve segment. Since December 2010, more than 260,000 volunteers world wide have participated, contributing over 20 million classifications. We have demonstrated the success of a citizen science approach with the project's more than 20 planet candidates, the discovery of PH1b, a transiting circumbinary planet in a quadruple star system, and the discovery of PH2-b, a confirmed Jupiter-sized planet in the habitable zone of a Sun-like star. I will provide an overview of Planet Hunters, highlighting several of project's most recent exoplanet and astrophysical discoveries. Acknowledgements: MES was supported in part by a NSF AAPF under award AST-1003258 and a American Philosophical Society Franklin Grant. We acknowledge support from NASA ADAP12-0172 grant to PI Fischer.

103.02 – Flicker, Jitter, Crackle: Lifting the Veil on Stellar Variability and Understanding its Impact on Planet Detection with Kepler

Fabienne A. Bastien[1], Keivan Stassun[1, 4], Gibor S. Basri[2], Joshua Pepper[3, 1]
1. Vanderbilt University, Madison, TN, United States. 2. University of California, Berkeley, CA, United States. 3. Lehigh University, Bethlehem, PA, United States. 4. Fisk University, Nashville, TN, United States.

The high-precision light curves obtained by NASA's Kepler mission unveiled a rich variety of photometric behavior in Sun-like stars. Using only long-cadence light curves and different ways of characterizing the stellar photometric variability, we examine how magnetic activity and radial velocity (RV) "jitter" both manifest photometrically. First, we present a unified picture of how the photometric behavior of Sun-like stars on time scales of hours to days evolves with time through an "evolutionary diagram" that involves only three simple measures of photometric variability. In this diagram, we observe clear evolutionary sequences: the light curves of the stars become "quieter" as the stellar spot coverage decreases with time, but they become suddenly and significantly more complex (they "crackle") as the stars approach their evolution off the main-sequence and spots no longer dominate the brightness variations. Using an asteroseismically analyzed sample of stars, we demonstrate that the sequences in our diagram are a strong function of stellar surface gravity, yielding a simple tool – "flicker" – to accurately measure surface gravity to better than 0.1 dex with just the long-cadence light curve. We next use this diagram to gain insight into the RV jitter of magnetically inactive stars, stars that exhibit RV jitter ranging from less than 3 m/s to over 130 m/s despite their low levels of magnetic activity and low levels of photometric variability. We find that photometric complexity ("crackle"), linked to higher frequency photometric variations, drives the RV jitter of these stars. Finally, we close the loop on our study with Ca II H&K magnetic activity measurements of over 700 Kepler stars, and we relate magnetic activity to our photometric variability evolutionary sequences.

103.03 – Optical variability of the Kepler AGN

Rick Edelson[1]
1. University of Maryland, College Park, MD, United States.

Kepler has opened a new era for the study of AGN optical variability, producing light curves with ~0.1% errors (for a ~15th magnitude source), 30 min sampling, >90% duty cycle and durations of years. Thanks to an intensive identification

campaign, the number of Seyfert 1s/quasars monitored by Kepler rose from just one (Zw 229-15) in the first year to 37 by the time of May 2013 reaction wheel failure. We measured the optical power spectral density (PSD) functions of these Kepler AGN finding that that on timescales of ~6 hr to 1 month, the PSDs are typically well-fitted with a slop of ~-3, steeper than seen in the X-rays. In a few sources there is also evidence for a flattening at the longest timescales. We also find a broad correlation between rms variability and flux level. These results broadly support the model in which the optical fluctuations are due to vicious instabilities in the accretion disk. I will also present the light curve for W2R1926+42, the only rapidly variable BL Lac object known to be monitored by Kepler. With data covering over a year and sampling rates of 1-30 min, this may be the information-richest AGN light curve ever gathered at any wavelength. The PSD appears to bend from a slope of -2.6 to -1.2 on a ~7 hr timescale, but fits are formally unacceptable. These data indicate that the phenomenon of blazar "microvariability" (sporadic variations on timescales shorter than the ~12 hour window available from the ground) actually results from a combination of rapid, powerful variability interspersed with longer, relatively quiescent periods.

104 – Exoplanets: Exomoons and Migration
Oral Session – National Harbor 12 – 06 Jan 2014 10:00 am to 11:30 am

104.01 – Open Cluster Planets and an Observational Constraint on Hot Jupiter Migration

Samuel N. Quinn[1], Russel J. White[1], David W. Latham[2], Lars A. Buchhave[2], Guillermo Torres[2], Robert P. Stefanik[2]
1. Georgia State University, Atlanta, GA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

In the absence of a third body, the orbits of short period giant planets should circularize due to tidal forces from their host stars. However, the youngest and most distant hot Jupiters may have circularization timescales larger than the age of the system. These "dynamically young" planets would not have had time to tidally circularize. If hot Jupiters form primarily through Type II migration, which is expected to preserve circular orbits, then both dynamically young and old planets should be found on circular orbits. On the other hand, if the migration process can impart significant eccentricity, as is the case for planet-planet scattering, there should be an observable difference between the eccentricity distributions of dynamically young and dynamically old hot Jupiters. We use our discovery of the eccentric Hyades planet HD285507b to highlight this analysis and conclude that planet-planet scattering plays an important role in hot Jupiter migration.

104.02 – Planetesimal Migration and its Effects on Mean Motion Resonances

Sourav Chatterjee[1], Eric B. Ford[2]
1. University of Florida, Gainesville, FL, United States. 2. Pennsylvania State University, University Park, PA, United States.

The Kepler mission has discovered much smaller (presumably lower-mass) planets than the radial velocity (RV) surveys. The period ratio distribution for the Kepler planet candidates (KPC) is different from that for the RV planets. The RV planets show an over density near integer period ratios. In contrast, KPCs show a dearth of systems at exact integer period ratios but an over density of pairs with period ratios slightly above exact commensurability. Due to the relatively lower masses of the KPCs (compared to RV planets) we find that it is important to consider changes in their orbits due to interaction with a residual planetesimal disk. We find that planetesimal migration can destroy mean motion resonances (MMR). For a large range in planetesimal-disk properties, planetesimal migration moves the orbits of planet pairs initially trapped in MMRs further apart explaining the observed asymmetry in KPC period ratio distribution near MMRs.

104.03 – How Do Mini-Neptunes Migrate?

Zachory K. Berta-Thompson[1]
1. MIT, Cambridge, MA, United States.

To understand an exoplanet, we need to know how it got where it is today. Because it transits a very nearby, very small star, the exoplanet GJ1214b is a useful laboratory for studying the physics of planets near the fuzzy boundary between super-Earths and sub-Neptunes. However, little is known about how GJ1214b migrated to its current close-in orbit. Was it scattered wildly inward and later tidally circularized, as many hot Jupiters appear to have been? Or was it coaxed in smoothly and gently, as seems to be the case for the compact, coplanar, small-planet systems uncovered by Kepler? To address this conundrum, we search for and analyze recurrent starspot occultations in closely-spaced transit light curves of GJ1214b taken with the Magellan, Gemini, and Hubble telescopes. We use these spot occultations to constrain the relative orientation of the planet's orbit to the host star's spin axis, which can be used to distinguish among possible scenarios for the migration history of the planet. This analysis bears not only on the one particularly useful GJ1214b system, but also on the processes that may shape many of the abundant close-in, low-mass, low-density exoplanets that populate our Galaxy.

104.04 – First Evaluation of the Rate of Planet Migration Into Stars, Plus Many Newly-Found Correlations Between Metallicity and Planet Orbit Parameters

Stuart F. Taylor[1, 2]
1. Participation Worldscope, Hong Kong, Hong Kong. 2. Global Telescope Science, Cottonwood, AZ, United States.

We give the first presentation of the relationship between the rate of planet migration into stars and the strength of tidal dissipation in the star. We also present several new correlations between metallicity and planet orbit parameters. We found that iron-rich systems have planet orbits with higher eccentricities. We find profoundly different patterns in the orbital distributions of iron rich and iron poor systems, with different peaks and gaps. The orbital distribution of planets of single stars versus stars with stellar companions are different as well. We show that ongoing planet migration can significantly

shape the occurrence distribution. We agree that higher initial iron abundance led to more crowded planet formation leading to more giant planet scattering, resulting in a correlation between eccentric planet orbits and stellar iron abundance (Dawson et al.). In order to fully explain these detailed patterns, we hypothesize that the iron abundance in stars is further increased by scattering sending planets into the star. The rate of planet migration will be seen as a parameter essential to understanding planet migration process, as well as understanding the strength of tidal dissipation. It will also be essential to understand how planet migration and the metallicity-dependent distribution of planets are related.

104.05 – Exomoon Conditions in Circumbinary Habitability Zones

Paul A. Mason[1, 3], Jorge I. Zuluaga[2], Joni Clark[3], Pablo Cuartas-Restrepo[2]
1. Univ. Of Texas at El Paso, Las Cruces, NM, United States. 2. Universidad de Antioquia, Medellin, Colombia. 3. New Mexico State University, Las Cruces, NM, United States.

Limits on the potential habitability of exomoons orbiting massive planets within circumbinary habitable zones are examined. Exomoons orbiting planets in the habitable zones of single stars and those orbiting circumbinary planets are subject to the, sometimes intense, tidal heating of the planet. So, exomoon orbits need to be sufficiently large and circular to avoid loss of water like Io. However, moons may be lost if their orbits are too large. We show that, in some cases, massive circumbinary planets have larger Hill radii than similar mass planets in single star habitable zones. The range of semimajor axes, beyond the habitable edge for moons is several times larger in some binaries as compared to single stars and is verified by numerical orbit experiments. We discuss implications of this result in the context of the binary habitability mechanism.

104.06 – Taking Exomoons to the (Radius) Limit

Natalie R. Hinkel[1], Stephen R. Kane[1]
1. San Francisco State University, San Francisco, CA, United States.

Moons around extrasolar planets are the next up-and-coming objects to be not only observed, but characterized for possible habitability. As with planets orbiting stars, exomoons have a limiting radius at which they are gravitationally bound, or the Hill radius. At a particular distance, they may also become tidally locked and therefore be in a synchronous rotation with the host-planet. We have examined the flux phase profile of a simulated, hypothetical moon orbiting at a distant radius around the confirmed exoplanets μ Ara b, HD 28185 b, BD +14 4559 b, and HD 73534 b. The irradiated flux on an exomoon at it's furthest, stable distance from the planet achieves its largest flux gradient, which places a limit on the flux ranges expected for subsequent (observed) moons closer in distance. We have also analyzed the effect of planetary eccentricity and time spent within the habitable zone on the flux on the moon. From stellar contributions alone, we find moons with host-planets fully within the habitable zone experience thermal equilibrium temperatures above the runaway greenhouse limit, requiring a small heat redistribution efficiency. In contrast, exomoons orbiting planets that only spend a fraction of their time within the habitable zone require a heat redistribution efficiency near 100% in order to achieve temperatures suitable for habitability. In other words, a planet might not need to spend its entire orbit within the habitable zone in order for the exomoon to be potentially habitable. In this way our findings separate exomoons and exoplanets, but it broadens the scope of worlds that may occupy a habitable zone.

105 – Extrasolar Planet Characterization & Theory I
Oral Session – Maryland Ballroom A – 06 Jan 2014 10:00 am to 11:30 am

105.01 – Earth-Size Planets from Kepler

Geoffrey W. Marcy[1], Erik Petigura[1], Andrew Howard[2], Lauren M. Weiss[1], Howard T. Isaacson[1], Leslie Rogers[3]
1. UC Berkeley, Berkeley, CA, United States. 2. University of Hawaii/IfA, Honolulu, HI, United States. 3. Caltech, Pasadena, CA, United States.
Contributing teams: Kepler Team

We report measurement of the occurrence of Earth-size planets in the habitable zone from the NASA Kepler Mission. We also report on the masses and radii for all known transiting planets smaller than 5 Earth-radii, revealing the transition from gas-laden to rocky planets. We also report new radii, masses and densities for 16 planets, most being smaller than 3 Earth-radii. We also report on the measurement of the mass and density of an Earth-size planet.

105.02 – Just the Photometry: Constraining exoplanet orbits by measuring stellar densities

David Sliski[1], David M. Kipping[2]
1. Harvard University, Cambridge, MA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

One unique trick in toolkit of astronomers studying transiting exoplanets, is that the mean stellar density may be determined using the shape of the light curve, under various idealized assumptions such as a circular orbit and the target star is unblended. "Asterodensity profiling" seeks to exploit this trick by comparing the light curve derived stellar density to that from some independent measurement. Any difference between the two measures indicates that one or more of the idealized assumptions are invalid. Therefore, the major challenge with single-planet systems (so-called "single-body asterodensity profiling" or SAP) is distinguishing whether the difference is due to a blend, orbital eccentricity or some combination. By careful consideration of the input priors, utilizing constraints from secondary eclipses and a Bayesian analysis of the system in question, the problem is tractable though, offering the chance to determine the underlying eccentricity distribution of exoplanets and even aid in validating planet candidates through blend analysis. In this talk, I will discuss single-body asterodensity profiling (SAP) for targets with asteroseismologically determined stellar densities, which is generally considered a gold-standard measure. We have investigated several targets with the largest apparent discrepancies between the transit-derived stellar density and that from asteroseismology. By independently detrending and fitting the transit light curves, we have calculated a revised value of this crucial ratio, with various priors tried. I will present the current results our work and discuss implications for the eccentricity and blend validation of these studied systems. I will finish by exploring the exciting potential of this technique in the TESS-era, where the fact our technique requires bright-star photometry alone, opens the door to constraints for hundreds/thousands of objects.

105.03 – NPOI Observations of the Exoplanet Host Kappa Coronae Borealis

Ellyn K. Baines[1], J. T. Armstrong[1], Gerard van Belle[2]
1. Naval Research Laboratory, Washington, DC, United States. 2. Lowell Observatory, Flagstaff, AZ, United States.

Kappa Coronae Borealis is a "retired A star", otherwise known as a former A-type dwarf that is now a K-type subgiant. It is a particularly fascinating target because of its unusual configuration of companions and dust rings. It hosts at least one exoplanet and perhaps two, and features a single wide dust ring or two narrow ones. We observed the star interferometrically in order to characterize the main star and the environment in which the planet(s) and dust ring(s) reside. We determined a variety of fundamental parameters for kappa CrB: the limb-darkened angular diameter, physical size, effective temperature, luminosity, mass, age, and the extent of the habitable zone range. We combined our mass with the orbital parameters from four sources from the literature to calculate the planet's mass as well.

105.04 – A Relation between Mass and Radius for 59 Exoplanets Smaller than 4 Earth Radii

Lauren M. Weiss[1, 2], Geoffrey W. Marcy[1]
1. UC Berkeley, Berkeley, CA, United States. 2. NSF, Washington, DC, United States.

We study the masses and radii of the 59 known exoplanets smaller than 4 Earth radii. We find a linear relation of the form M ? 3R, in units of Earth masses and radii. The RMS of planet masses is 3.8 Earth masses, and our best fit has reduced ?2 = 3.4, indicating a large diversity in planet compositions among small planets. Wu & Lithwick (2013), who also find M ? 3R for

a different sample of small exoplanets characterized primarily with transit timing variations, note that the linear scaling is consistent with a constant escape velocity.

105.05 – The Fate of Hot Jupiters

Kevin Schlaufman[1]
1. MIT Kavli Institute for Astrophysics and Space Research, Cambridge, MA, United States.

The properties of exoplanet systems are both observed and theoretically suggested to strongly depend on the mass, metallicity, and evolutionary state of their host stars. One example is that evolved stars do not host hot Jupiters. Tidal evolution is one possible explanation, though the possibility that the evolved stars are more massive than the FG-type stars that dominate the main-sequence sample complicates the interpretation. However, I'll show that the Galactic space motions of the evolved host stars demand that on average they be similar in mass to main-sequence FG type planet-hosts. The two samples therefore differ only in age, and provide a glimpse of the same exoplanet population both before and after tidal evolution.

105.06 – Exoplanet Transit Spectroscopy of Hot Jupiters Using HST/WFC3

Avi Mandell[1], Korey Haynes[2, 1], Evan Sinukoff[3], Nikku Madhusudhan[4], Adam S. Burrows[5], Drake Deming[6, 1]
1. NASA GSFC, Greenbelt, MD, United States. 2. George Mason University, Fairfax, VA, United States. 3. University of Hawaii, Honolulu, HI, United States. 4. Yale University, New Haven, CT, United States. 5. Princeton University, Princeton, NJ, United States. 6. University of Maryland, College Park, MD, United States.

The Wide Field Camera 3 (WFC3) on the Hubble Space Telescope (HST) provides the potential for spectroscopic characterization of molecular features in exoplanet atmospheres, a capability that has not existed in space since the demise of NICMOS on HST and the IRS on Spitzer. We present analysis of transit spectroscopy for three extrasolar planets observed during the HST Cycle 18: WASP-12 b, WASP-17 b, and WASP-19 b. WASP-12 b and WASP-19 b are two of the hottest exoplanets discovered to date, while WASP-17 b has a much lower equilibrium temperature but has one of the largest atmospheric radii of known transiting planets; measurement of molecular absorption in the atmospheres of these planets offers the chance to explore several outstanding questions regarding the atmospheric structure and composition of these highly irradiated, Jupiter-mass objects. The observations cover a single primary transit for each planet, and we analyze the data using a strategy that allows us to correct for channel- or wavelength-dependent instrumental effects by utilizing the band-integrated time series and measurements of the drift of the spectrum on the detector over time. We achieve almost photon- limited results for individual spectral bins, but the uncertainties in the transit depth for the the band-integrated data are exacerbated by the uneven sampling of the light curve imposed by the orbital phasing of HST's observations. Our final transit spectra for all three objects are consistent with the presence of a broad absorption feature at 1.4 microns, most likely due to water. However, the amplitude of the absorption is less than that expected based on previous observations with Spitzer, possibly due to hazes absorbing in the NIR or non-solar compositions. The degeneracy of models with different compositions and temperature structures combined with the low amplitude of any features in the data preclude our ability to place unambiguous constraints on the atmospheric composition, but future observations with WFC3 to improve the S/N and/or a comprehensive multi-wavelength analysis will allow us to better distinguish between different models.

105.07 – On the Coplanar Origin of Counter Orbiting Hot Jupiters

Gongjie Li[1], Smadar Naoz[1], Bence Kocsis[1], Abraham Loeb[1]
1. Harvard Univ., Cambridge, MA, United States.

Some hot Jupiters are observed to orbit in exactly the opposite direction to the spin of their host star. This ~180 degree misalignment cannot be well explained with previously proposed physical processes. Here we present a mechanism that can naturally lead to these counter-orbiting systems. The gravitational influence of an outer eccentric object in a coplanar orbit increases the initial eccentricity of the planet to high values. The planet's orbit then suddenly flips by ~180 degree, rolling over its major axis. The ~180 degree flip criterion and timescale are given by simple analytic expressions that depend on the initial orbital parameters. With tidal dissipation, this mechanism naturally leads to the observed counter-orbiting systems.

105.08 – The Spitzer/IRAC 4.5 micron full-orbit phase curve of the hot Jupiter HD 209458b

Robert Zellem[1], Nikole Lewis[2], Heather Knutson[3], Caitlin A. Griffith[1], Jonathan J. Fortney[4], Adam P. Showman[1], Nicolas B. Cowan[5], Eric Agol[6], Adam S. Burrows[7], David Charbonneau[8], Drake Deming[9], Gregory P. Laughlin[4], Jonathan S. Langton[10]

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The hot Jupiter HD 209458b is one of the most favorable targets for full-orbit phase curve observations, as it is one of the brightest systems (V-mag = 7.65, K-mag = 6.308), has a large planet-to-star contrast, and offers a high signal-to-noise ratio and the ability to make high-precision measurements. This planet also serves as the archetype for a class of planets that have dayside temperature inversions; the differences between this class of planets and those lacking inversions (including HD 189733b) are currently not well-understood. Here we present the first full-orbit phase curve of HD 209458b observed with the Spitzer/IRAC 4.5 micron photometric band. Our data, which includes one primary transit and two secondary eclipses, was reduced with a pixel-mapping method to get within 1.145 times the photon noise limit. We measure the brightness temperature of the observed phase curve. The results are modeled with radiative transfer models along with other primary transit and secondary eclipse data to determine the pressure level of the emissions. We then compare these results to predictions from global circulation models, including those where magnetic effects and thermal inversions are present in order to determine the effect that HD 209458b's dayside temperature inversion has on its atmospheric circulation and chemistry.

105.09 – Experimental study of a low-order wavefront sensor for high-contrast coronagraphic imagers

Julien Lozi[1], Ruslan Belikov[2], Glenn Schneider[1], Olivier Guyon[1], Sandrine Thomas[2, 3], Eugene Pluzhnik[2, 3]

1. University of Arizona, Tucson, AZ, United States. 2. NASA Ames Research Center, Moffett Field, CA, United States. 3. UARC/NASA Ames, Moffett Field, CA, United States.
Contributing teams: EXCEDE Project Technology Development Team

For the technology development of the mission EXCEDE (EXoplanetary Circumstellar Environments and Disk Explorer) – a 0.7 m telescope equipped with a Phase-Induced Amplitude Apodization Coronagraph (PIAA-C) and a 2000-element MEMS deformable mirror, capable of raw contrasts of 1e-6 at 1.2 λ/D and 1e-7 above 2 λ/D – we developed a test bench simulating it's key components. To achieve this level of contrast, one of the main goals is to remove low-order aberrations, using a Low-Order WaveFront Sensor (LOWFS). An experiment simulating the starlight suppression system is currently developed at NASA Ames Research Center, and includes a LOWFS controlling tip/tilt modes in real time at 1 kHz. The LOWFS allowed us to reduce the tip/tilt disturbances to 1e-3 λ/D rms, letting us achieve a contrast of 4e-7 between 1.2 and 2 λ/D. Also by studying accurately this system, and by comparing it to simulations, we are able to deduce its performances on different coronagraphs – different sizes of telescopes, inner working angles, contrasts, etc. – and therefore study its contribution beyond EXCEDE.

106 – Galaxy Clusters: Star Formation, AGN, Interactions

Oral Session – National Harbor 10 – 06 Jan 2014 10:00 am to 11:30 am

106.01D – Star Formation in Cluster Dwarf Galaxies

Cody Rude[1], Wayne Barkhouse[1]
1. University of North Dakota, Grand Forks, ND, United States.

The evolution of galaxies in dense environments can be affected by close encounters with neighboring galaxies and interactions with the intracluster medium (ICM). Dwarf galaxies may be especially susceptible to these effects due to their low mass. The goal of my dissertation research is to look for signs of enhanced star formation in cluster dwarf galaxies by measuring the *r*- and *u*-band luminosity functions of several galaxy clusters using archival data from the Canada-France-Hawaii Telescope. Luminosity functions are created using various clustercentric annuli from stacked cluster data. To account for differences in cluster optical richness, each cluster is scaled according to r200, where r200 is the radius of a sphere, centered on the cluster, whose average density is 200 times the critical density of the universe. An increase in the faint-end slope of the *u*-band luminosity function relative to the *r*-band indicates possible enhanced star formation. The location of the enhanced star formation from the cluster center may yield insights into what physical mechanisms are at work. In the cluster center, ram pressure from the ICM may; 1) compress the gas within a galaxy causing enhanced star formation, 2) remove the gas thus quenching star formation, or 3) compress and then remove the gas resulting in a burst of star formation followed by truncation. Alternatively, enhanced star formation near the edge of a cluster may signify galaxy-galaxy interactions as the dominant star formation mechanism as the ICM is generally less dense in this region.

106.02D – Modeling AGN Feedback in Cool-Core Clusters

Yuan Li[1]
1. Columbia University, New York, NY, United States.
Contributing teams: Enzo

We perform high-resolution adaptive mesh refinement simulations to study the impact of momentum-driven AGN feedback in cool-core clusters. Run-away cooling first happens only in the central 50 pc region while no local instability develops outside the very center of the cluster. The gas is accreted onto the super-massive black hole which powers AGN jets at an increasing rate as the entropy continues to decrease in the core. Cold clumps of gas first form along the propagation direction of the AGN jets due to non-liner thermal instability. The cold clumps eventually fall to the center and feed the super-massive black hole, increasing its power which causes the core entropy to increase and thus slows down the cooling of the intra-cluster medium. A dynamical balance between AGN heating and gas cooling is maintained over a 10 Gyr time scale. The general morphology, spacial distribution and the estimated Hα luminosity of the cold gas are in reasonable agreement with observations.

106.03 – The Spectacular Interacting Galaxy System Arp 105

Michael West[1], Michael Gregg[2, 3]
1. Maria Mitchell Observatory, Nantucket, MA, United States. 2. University of California, Davis, Davis, CA, United States. 3. Lawrence Livermore National Lab, Livermore, CA, United States.

We present a study of one of the most remarkable examples of ongoing galaxy mergers, Arp 105, which resides in the nearby rich cluster Abell 1185. The result of a violent encounter between a spiral galaxy and a larger elliptical, Arp 105 is characterized by a long plume of material that ends in a spray of stars and star clusters more than 100 kpc to the north. Over time, this material will diffuse throughout Abell 1185, augmenting the intergalactic populations of stars, globular clusters, dwarf galaxies and gas already present. Analysis of WFPC2 images obtained with HST provides compelling evidence of the existence of old star clusters in the tidal tail and main body of Arp 105, many of which are likely to escape into intergalactic space, as well as the presence of some young clusters that might have been created in situ from the tidal debris.

106.04 – Star Formation in the Double Galaxy Cluster Abell 2465

Gary A. Wegner[1], Devin S. Chu[2]
1. Dartmouth College, Hanover, NH, United States. 2. Dartmouth College, Hanover, NH, United States.

We investigated the star formation rate and location of galaxies with star formation in the double merging cluster Abell 2465 at z = 0.245. Hα emission measurements of the galaxies in the cluster were made with the 2.4 m telescope at the MDM Observatory using an interference filter centered on the redshifted Hα line at a wavelength of 817 nm. The resulting Hα fluxes were converted to star formation rate using Kennicut's formula. The mass normalized star formation rate, ?SFR/M_{200}, per cluster is found to be enhanced relative to published galaxy cluster relations as a function of z and M_{200}. We discuss the morphologies of the strongest emitters, many of which appear to be mergers, and the X-ray structure of the cluster from

106.05 – Weighing "El Gordo" with a Precision Scale: Hubble Space Telescope Weak-lensing Analysis of the Merging Galaxy Cluster ACT-CL J0102-4915 at z=0.87

Myungkook J. Jee[1], John P. Hughes[2], Felipe Menanteau[3, 2], Cristobal Sifon[4], Rachel Mandelbaum[5], Felipe Barrientos[6], Leopoldo Infante[6], Karen Ng[1]
1. UC Davis, Davis, CA, United States. 2. Rutgers University, Piscataway, NJ, United States. 3. NCSA, Urbana, IL, United States. 4. Leiden University, Leiden, Netherlands. 5. Carnegie Mellon University, Pittsburgh, PA, United States. 6. Pontificia Universidad, Santiago, Chile.

We present a HST weak-lensing study of the merging galaxy cluster "El Gordo" (ACT-CL J0102-4915) at z=0.87 discovered by the Atacama Cosmology Telescope collaboration as the strongest SZ decrement in its ~1000 sq. deg survey. Our weak-lensing analysis confirms that ACT-CL J0102-4915 is indeed an extreme system consisting of two massive (~10^15 Msun each) subclusters with a projected separation of ~0.7 Mpc. This binary mass structure revealed by our lensing study is consistent with the cluster galaxy distribution and the dynamical study carried out with 89 spectroscopic members. The lensing-based velocity dispersions are consistent with their spectroscopic measurements. The centroids of both components are tightly constrained (~4") and close to the optical luminosity centers. The X-ray and mass peaks are spatially offset by ~13" (~100 kpc), which is significant at the ~3 sigma confidence level and confirms that the baryonic and dark matter in this cluster are disassociated. The dark matter peak, however, does not lead the gas peak in the direction expected if we are viewing the cluster soon after first core passage during a high speed merger. Extrapolation of the two NFW halos to a radius r200a=2.4 Mpc yields a combined mass of M200a=(3.10+-0.70) x 10^15 Msun. This extrapolated total mass is consistent with our two-component-based dynamical analysis and previous X-ray measurements, projecting ACT-CL J0102-4915 to be the most massive cluster at z>0.6 known to date.

106.06 – The Radio Relics and Halo of El Gordo: a Massive Cluster Merger at z = 0.870

Andrew J. Baker[1], Robert Lindner[1, 2], Nicholas Battaglia[3], Neeraj Gupta[4], John P. Hughes[1], Kenda Knowles[5], Tobias Marriage[6], Felipe Menanteau[7], Kavilan Moodley[5], Erik D. Reese[8], Raghunathan Srianand[4]
1. Rutgers, the State University of NJ, Piscataway, NJ, United States. 2. University of Wisconsin, Madison, WI, United States. 3. Carnegie Mellon University, Pittsburgh, PA, United States. 4. Inter-University Centre for Astronomy and Astrophysics, Pune, India. 5. University of KwaZulu-Natal, Durban, South Africa. 6. Johns Hopkins University, Baltimore, MD, United States. 7. University of Illinois, Urbana, IL, United States. 8. University of Pennsylvania, Philadelphia, PA, United States.

We present 610 MHz and 2.1 GHz imaging of the massive Sunyaev-Zel'dovich effect selected z = 0.870 cluster merger ACT-CL J0102-4915 ("El Gordo"), obtained with the Giant Metre-wave Radio Telescope (GMRT) and the Australia Telescope Compact Array (ATCA), respectively. We detect two complexes of radio relics along the system's northwest-to-southeast collision axis whose polarization and spectral index properties are consistent with their creation via Fermi acceleration by shocks in the intracluster medium triggered by the cluster collision. Our wide-bandwidth, full-polarization ATCA data allow us to compute the Faraday rotation measure and infer a magnetic field strength for the northwest relic. In addition to the relics, we detect a large, powerful radio halo whose centroid and shape match those of El Gordo's X-ray morphology. The halo's 610 MHz to 2.1 GHz spectral index is flattest near the relics, along the system's collision axis, and in regions of high gas temperature-- all regions associated with recent energy injection. The spatial and spectral correlation between the halo emission and cluster X-ray properties points to a primary mechanism like turbulent reacceleration as the halo's origin, reinforcing the conclusions of recent analyses of scaling relations in moderately large cluster samples. This work has been supported by NSF grant AST-0955810.

106.07 – A Deep Chandra X-ray Observation of El Gordo

John P. Hughes[1], Andrew J. Baker[1], Felipe Barrientos[2], Myungkook J. Jee[3], Leopoldo Infante[2], Robert Lindner[4], Rachel Mandelbaum[5], Felipe Menanteau[6], Cristobal Sifon[7], Adi Zitrin[8]
1. Rutgers Univ, Piscataway, NJ, United States. 2. Pontifica Univ Catolica de Chile, Santiago, Chile. 3. UC Davis, Davis, CA, United States. 4. Univ of Wisconsin, Madison, WI, United States. 5. Carnegie Mellon Univ, Pittsburgh, PA, United States. 6. NCSA, Urbana-Champaign, IL, United States. 7. Lieden Univ, Lieden, Netherlands. 8. Univ of Heidelberg, Heidelberg, Germany.

We present new results on ACT-CL J0102-4915 ("El Gordo") based on a deep Chandra observation. We present a temperature map on sub-arcminute scales that shows significant variations from a low of 5 keV near the location of the brightest cluster

galaxy (BCG) to a high of 25 keV. The cold core shows evidence for a cold front, an interface across which the temperature decreases while the density rises, providing further evidence for a major merger in El Gordo. We also examine the locations of merger shocks as traced by radio relics to search for density and temperature jumps in the hot cluster gas. The BCG, which is significantly bluer than expected from a passively evolving elliptical galaxy, is offset by some 5-10 arcseconds from the peak X-ray surface brightness. We relate the density and temperature structures visible in the Chandra data with our recent results from gravitational lensing analyses of El Gordo.

107 – HAD IV: History of Astronomy
Oral Session – National Harbor 3 – 06 Jan 2014 10:00 am to 11:30 am

107.01 – We Are NOT Alone!

Elizabeth Griffin[1]
1. Dominion Astrophysical Observatory, Victoria, BC, Canada.

Astronomy has many caches of valuable data. In addition to the ever-expanding databases from modern surveys, there are also photographic archives of historic observations, each a unique image of some event, object or spectrum - a once-only observation, and a one-only version. Analogue data like that cannot be copied; they are precious, fragile, and imperilled. They are essential for time-sensitive research but cannot be ingested into modern analyses until they have been correctly and completely digitized, a procedure that is not easy, not cheap, and not commonly found. This story is not new, but what IS new to many astronomers is the realization that other sciences are in just the same, or even worse, predicament. In other sciences, historic data may be heaps of record sheets, the ink fading and the paper attacked by vermin. Unlike astronomy, whose plates are neatly filed in observatory plate vaults, and carefully card-catalogued, other sciences look for their historic data in uncharted territory, often relying on word of mouth or chance for their discovery and recovery. The situation must be addressed before the records and photographs degrade to being unuseable. Individual sciences have to compete with one another for funds to translate their analogue data into manageable electronic versions, but if the individual challenges are federated into a global scientific project, with Astronomy being just one partner that also has good experience to share, the problem becomes a recognized, international shared concern. Its solution will enable all sciences (and thereby human knowledge) to become become much better informed. The talk will demonstrate that claim through specific examples, and will also bring the HAD up to date on the progress being made to provide rapid and reliable access to the historic astronomical data of the world.

107.02 – The Astronomy Genealogy Project

Joseph S. Tenn[1]
1. Sonoma State University, Rohnert Park, CA, United States.

The Astronomy Genealogy Project, to be known as AstroGen, will list as many as possible of the world's astronomers with their academic parents (aka thesis advisors) and enable the reader to trace both academic ancestors and descendants. It will be very similar to the highly successful Mathematics Genealogy Project (MGP), available at http://genealogy.math.ndsu.nodak.edu. The MGP, which has been in operation since 1996, now contains the names of about 170,000 "mathematicians." These include many physicists and astronomers, as well as practitioners of related sciences. Mitchel Keller, the director of the MGP, has generously shared the software used in that project, and the American Astronomical Society (AAS) will host AstroGen, a project of the Historical Astronomy Division, on its website. We expect to start seeking entries soon, depending on the availability of computational assistance from the AAS IT department. We are seeking volunteers to help run the project. If you are interested, please contact me at joe.tenn@sonoma.edu.

107.03 – East, West, North, South: A look at a method available to prehistoric cultures to both determine cardinality and the date of the equinox

Anthony B. Hull[3], Carol Ambruster[2], Elizabeth Jewell[1]
1. University of Phoenix, Philadelphia, PA, United States. 2. AAS Emeritus , Philadelphia, PA, United States. 3. University of New Mexico, Albuquerque, NM, United States.

Many prehistoric world cultures have public and sacred buildings and roads which may exhibit cardinality (alignment to the true cardinal directions) to impressive precision. Careful alignment of such buildings would seem a means to relate the ground hemisphere to the celestial hemisphere. Not all prehistoric cultures cared about true cardinality, but apparently many did. Even today, lacking surveying instruments or GPS, determination of the cardinal directions, even to ±1-2 degrees, is challenging. In this paper we examine how these directions could have been accurately determined by prehistoric peoples with attentive observation using simply a gnomon. While we will not examine here their models of the cosmos, nor why they would construct to these alignments, we do examine expected systematic and random errors in such determinations if a gnomon is used. Our models demonstrate that marking the shadow locus from a gnomon not only can inform on cardinality to remarkable precision, but also is capable of giving the date of equinox to perhaps ±1-2days

107.04 – Graeco-Roman Astro-Architecture: The Temples of Pompeii

Vance R. Tiede[1]
1. Astro-Archaeology Surveys, Guilford, CT, United States.

Roman architect Marcus Vetruvius Pollio (ca. 75-15 BC) wrote, "[O]ne who professes himself as an architect should be...acquainted with astronomy and the theory of the heavens.... From astronomy we find the east, west, south, and north, as

well as the theory of the heavens, the Equinox, Solstice and courses of the Stars." (De Architectura Libri Decem I:i:3,10). In order to investigate the role of astronomy in temple orientation, the author conducted a preliminary GIS DEM/Satellite Imaging survey of 11 temples at Pompeii, Italy (N 40d 45', E 14d 29'). The GIS survey measured the true azimuth and horizon altitude of each temple's major axis and was field checked by a Ground Truth survey with theodolite and GPS, 5-18 April 2013. The resulting 3D vector data was analyzed with Program STONEHENGE (Hawkins 1983, 328) to identify the local skyline declinations aligned with the temple major axes. Analysis suggests that the major axes of the temples of Apollo, Jupiter and Venus are equally as likely to have been oriented to Pompeii's urban grid, itself oriented NW-SE on Mt. Vesuvius' slope and hydraulic gradient to optimize urban sewer/street drainage (cf. Hodge 1992). However, the remaining nine temples appear to be oriented to astronomical targets on the local horizon associated with Graeco-Roman calendrics and mythology. TEMPLE/ DATE/ MAJOR AXIS ASTRO-TARGET (Skyline Declination in degrees) Public Lares/AD 50/ Cross-Quarter 7 Nov/3 Feb Sun Set, Last Gleam (-16.5) Vespsian/ AD 69-79/ Cross-Quarter 7 Nov/3 Feb Sun Set, LG (-16.2) Fortuna Augusta/ AD 1/ Winter Solstice Sun Set, LG (-22.9) Aesculapius/ 100 BC/ Perseus Rise (β Persei-Algol = +33.0) & Midsummer Moon Major Stand Still Set, LG (-28.1) Isis/ 100 BC/ Midwinter Moon Major Stand Still Rise, Tangent (+28.5) & Equinox Sun Set, Tangent (-0.3) Jupiter/ 150 BC/ ? Scorpionis-Sargas Rise (-38.0) Apollo/ 550 (rebuilt 70 BC)/ α Columbae-Phact Rise (-37.1) Venus/ 150 BC (rebuilt 70 BC)/ α Columbae-Phact Rise (-37.7) Ceres/ 250 BC/ Midsummer Moon Major Stand Still Set, LG (-27.9) Dioysyus/ 250 BC/ Equinox Sun Set, LG (+0.3) Doric/ 550 BC/ β Orionis-Rigel Rise (-14.6)

107.05 – The Talmudic Sage Samuel, the Pleiades and Comet 2P/Encke: An Ancient Jewish Astronomical Text Explained

Alan Gersch[1]

1. Univ. of Maryland, College Park, MD, United States.

The Babylonian Talmud is an ancient Jewish compendium of law and lore spanning from roughly the first through fifth centuries. Scattered throughout, amongst the non-legal material, there are many astronomical statements, some more scientifically accurate than others. In Tractate *Brachot* (58b) the rabbinic sage Samuel (c. 3rd century CE) who is known for his astronomical acumen, explains that *"Kimah"*, which is generally translated/identified as the Pleiades, is so called because it is "about a hundred". This is ostensibly a play on words: *"ke-meah"* means "about a hundred" in Hebrew. However, punning notwithstanding, given Samuel's knowledge of the visible sky, this statement is very puzzling. The number of stars in the Pleiades cluster visible to the naked eye is less than ten – hardly something that could be called "about a hundred", even given a Talmudic propensity for exaggeration! Modern astronomical methods may help shed light on this ancient text. Numerical integration of the orbit of Comet 2P/Encke, thought to be the progenitor of the Taurid meteors, may provide a novel explanation for this strange statement.

107.06 – Copernican Astronomy and Oceanic Exploration

Paul McKittrick[1]

1. Georgia Institute of Technology, Atlanta, GA, United States.

This paper examines the relationships between the century long development of the "New Astronomy" (Copernicus' axially rotating and solar orbiting earth, governed by Kepler's laws of planetary motion) of the sixteenth and early seventeenth centuries and the emerging astronomical navigation technologies of the fifteenth and sixteenth century Iberian oceanic explorers and their sixteenth and seventeenth century Protestant competitors. Since the first breakthroughs in Portuguese astronomical navigation in ascertaining latitude at sea were based upon the theories and observations of classically trained Ptolemaic astronomers and cosmographers, it can be argued that the new heliocentric astronomy was not necessary for future developments in early modern navigation. By examining the history of the concurrent revolutions in early modern navigation and astronomy and focusing upon commonalities, we can identify the period during which the old astronomy provided navigators with insufficient results – perhaps hastening the acceptance of the new epistemology championed by Galileo and rejected by Bellarmine. Even though this happened during the period of northern protestant ascendancy in exploration, its roots can be seen during pre-Copernican acceptance in both Lutheran and Catholic Europe. Copernican mathematics was used to calculate Reinhold's Prutenic Tables despite the author's ontological rejection of the heliocentric hypothesis. These tables became essential for ascertaining latitude at sea. Kepler's Rudophine Tables gained even more widespread currency across Europe. His theories were influenced by Gilbert's work on magnetism – a work partially driven by the requirements of English polar exploration. Sailors themselves never needed to accept a heliocentric cosmography, but the data they brought back to the metropolis undermined Ptolemy, as better data kept them alive at sea. This exchange between theoretician and user in the early modern period drove both ships and science. Copernican astronomers and the great explorers had reciprocal debts.

107.07 – Messier, Copernicus, Flamsteed: The SAF Rare-Book Collection in Paris

Jay M. Pasachoff[1]

1. Williams College, Williamstown, MA, United States.

The historic books belonging to the Société Astronomique de France, founded by Camille Flammarion in 1887, are located partly in Paris and partly at the Flammarion site in Juvisy, a Paris suburb. Their holdings include first editions of Copernicus's

De Revolutionibus and of Flamsteed's star atlas, as well as Messier's own copy of his 1783 and 1784 papers with his handwritten comments and additions. I will describe the fruitless search for a Bevis atlas and the circumstances that led me to inspect these treasures. I thank David Valls-Gabaud and Philippe Morel of the Société Astronomique de France for their hospitality in Paris, Jean-Claude Pecker, and Owen Gingerich for his prior work on Messier's catalogue.

107.08 – The Carbon Dioxide Concentration in Earth's atmosphere and Its Possible Influence on the Temperature at the Surface – as discussed in Sweden in 1894-96.

Lee Anne M. Willson[1]

1. Iowa State Univ., Ames, IA, United States.

On November 15, 1894, Arvid Högbom, geologist, presented a paper at a meeting of the Swedish Chemical Society ("Kemistsamfundet) in Uppsala. His title: "On the probability of secular changes in the atmosphere's carbonic acid concentration". The possibility that changes in the carbon dioxide concentration would produce changes in the surface temperature came up in the discussion after the talk. In the audience was Svante Arrhenius. In early 1896, at another meeting of Kemistsamfundet, Arrhenius followed up on this with a paper "The influence of the carbonic acid concentration on the temperature at the surface of the Earth". Both papers were published in Svensk Kemisk Tidscrift – Vol. 6 and Vol. 7 – as part of the minutes of the corresponding meetings. Arrhenius continued to pursue the idea, presenting and writing about it outside of Sweden. Most histories credit Arrhenius's work as the first on global warming, although some mention Högbom's prior report. Högbom's paper has never been translated from the Swedish, at least not so far as I have been able to discover. I will present a translation and review of Högbom's elegant paper and Arrhenius's initial response.

108 – HEAD I: News from the Galactic Center: A Multiwavelength Update on the Sgr A*/G2 Encounter

Special Session – National Harbor 5 – 06 Jan 2014 10:00 am to 11:30 am

The predicted collision between a dense, cold gas cloud (dubbed "G2") and our Milky Way's own supermassive black hole, Sgr A*, has sparked real-time observational and theoretical efforts across the entire astronomical community. G2's orbit is eccentric and the cloud already shows signs of tidal disruption by the black hole. This encounter offers an unprecedented opportunity to test models of black hole accretion and its associated feedback. Yet, despite impressive multiwavelength monitoring campaigns and substantial theoretical work, debate continues as to the nature of G2 and it's impact on Sgr A*: Is G2 really a cloud, or is it an enshrouded star? Will Sgr A*'s high energy flare rate increase during this encounter and can such an increase help constrain the flare mechanism? Can we use G2 as a probe of Sgr A*'s hot accretion flow? What changes do we observe from G2 itself as it is shocked and heated? What do we learn if nothing happens (electromagnetically speaking)? Join the AAS High Energy Astrophysics Division (and friends!) for a lively discussion about these and other controversies unfolding in our Galactic Center.

108.01 – A Brief Overview of X-ray Monitoring of the Sgr A*/G2 Interaction in 2012-2013

Frederick K. Baganoff[1]
1. MIT, Cambridge, MA, United States.
Contributing teams: Sgr A XVP Collaboration*

G2 is a dusty object on a nearly radial orbit toward the Galactic supermassive black hole, Sgr A*. Gillessen et al. (2012) propose that it is an about 3 earth-mass dusty gas cloud undergoing tidal disruption as it approaches pericenter in late 2013 or early 2014. Some models predict that the cloud will be shock heated and compressed to X-ray emitting temperatures and that it may reach 2-10 keV luminosities of a few times 10^{34} erg/s as the center of mass reaches pericenter. These models predict that the cloud will self-shock and that about half of its mass will gradually accrete onto the black hole over the next several decades, providing an unique opportunity to study accretion onto a black hole in the ultra-sub-Eddington accreting black hole. I will summarize the observational results of Chandra and XMM campaigns to monitor the interaction of G2 with Sgr A* in 2012 and 2013.

108.02 – G2 Monitoring at Submillimeter, Millimeter, and Radio Wavelengths

Geoffrey C. Bower[1]
1. ASIAA/RCUH, Hilo, HI, United States.

I will present results from ALMA, SMA, CARMA, and VLA monitoring of the total and polarized flux density of Sgr A* over the period from 2012 through 2013. Total flux density monitoring constrains the presence of an enhanced accretion flow as the G2 cloud disrupts. In addition, low frequency radio monitoring constrains the presence of a bow-shock from cloud accretion disk interaction. Analysis of the VLA Service Observing data allows us to place tight limits on the magnitude of the bow-shock emission. The polarized intensity permits us to explore changes in the accretion flow on scales of 10 Schwarzschild radii through changes in the intrinsic emission properties and on scales of thousands of Schwarzschild radii through Faraday rotation.

108.03 – The Swift/XRT monitoring campaign of the Galactic center

Nathalie Degenaar[1], Mark Reynolds[1], Jon M. Miller[1], Rudy Wijnands[3], Jamie A. Kennea[2], Daryl Haggard[4], Neil Gehrels[8], Gabriele Ponti[7], Frederick K. Baganoff[5], Sera Markoff[3], Diego Altamirano[6], David N. Burrows[2]
1. University of Michigan, Ann Arbor, MI, United States. 2. Penn State University, State College, PA, United States. 3. University of Amsterdam, Amsterdam, Netherlands. 4. Northwestern University, Evanston, IL, United States. 5. MIT, Cambridge, MA, United States. 6. University of Southampton, Southampton, United Kingdom. 7. MPE, Garching, Germany. 8. NASA GSFC, Greenbelt, MD, United States.

Starting in 2006, the Galactic center has been monitored on a nearly daily basis with the X-ray telescope on-board the Swift satellite. The short pointed observations have offered a unique view of the long-term X-ray behavior of Sgr A*, in particular of its X-ray flaring properties. The Swift campaign also provides an excellent setup to closely monitor the interaction of the supermassive black hole with the gaseous object G2. Because of the unique daily sampling, the Swift program may prove to serve as an important trigger for other observatories at different wavelengths. I will report on the latest results of the Swift X-ray monitoring campaign of the Galactic center.

108.04 – Expectations for Sgr A* in the case of an enhanced accretion rate from the G2 encounter

Sera Markoff[1]
1. API, University of Amsterdam, Amsterdam, Netherlands.
Contributing teams: Chandra X-ray Visionary Project on Sgr A*

Sgr A* is currently the weakest accreting black hole we can observe, but "light echoes" in fluorescent iron show that it was likely more active in the recent past. Encounters like G2 may be one way such bursts of activity are initiated, although it seems that in this particular case only a small fraction of an already small available mass will trickle down to the nucleus. If we are optimistic, however, we can anticipate what we might see in the case of an accretion rate enhancement. I will describe a few model predictions for G2-induced nuclear activity, from a reduction in flares, to lighting up the putative jets, or even G2 interactions with a passive outflow.

108.05 – Multi-Wavelength Monitoring of the G2 Cloud Interacting with Sgr A*

Farhad Yusef-Zadeh[1]
1. Northwestern Univ., Evanston, IL, United States.

Preliminary results of our ongoing VLA, VLBA, CARMA and Fermi monitoring of Sgr A* in coordination with Chandra will be presented. The main focus will be on accurate alignment of the radio and X-ray reference frames using three sources including the absolute position of the magnetar SGR J1745-29, light curves of Sgr A* at multiple radio wavelengths and structural details surrounding the inner 1 arcsecond of Sgr A*. These measurements will also examine the expected X-ray and radio light curves in the context of the jet interaction picture.

108.06 – G2 Encounter: A Real-time Experiment on Accretion Flows

Feryal Ozel[1]
1. University of Arizona, Tucson, AZ, United States.

There is by now ample evidence that the accretion flow around Sgr A* contains a low density high temperature plasma. Observations with the Chandra X-ray Observatory constrain the flow properties out near the Bondi radius, at around 10^5 Schwarzschild radii, while interpretations of the interferometric observations in the sub-mm provide a handle on the flow close to the black hole. The intermediate radii where G2 makes its closest approach to the black hole are the least well constrained from theory or observations. Similarly, there are indications from accreting black holes that strong outflows are commonplace and that the matter reaching the horizon is a small fraction of the matter entering the accretion flow but there is no consensus from theoretical calculations of the strength and the properties of the outflows. I will discuss how the encounter of G2 with Sgr A* provides a real-time experiment of the accretion flow in the intermediate radii and helps test accretion theory of inflows and outflows.

108.07 – Keck observations of G2 and SgrA*

Leo Meyer[1], Andrea M. Ghez[1], Tuan Do[2], Anna Boehle[1], Gunther Witzel[1], Breann Sitarski[1], Sylvana Yelda[1], Jessica R. Lu[3], Mark Morris[1], Eric E. Becklin[1]
1. UCLA, Los Angeles, CA, United States. 2. Dunlap Institute, Toronto, ON, Canada. 3. IfA, Honolulu, HI, United States.

We present observations and analysis of G2 – the gaseous red emission-line object that is fast approaching the central black hole on a very eccentric orbit. The laser guide star Adaptive Optics systems on the W. M. Keck I and II telescopes were used to obtained spectroscopy and imaging at the highest spatial resolution. We present the orbital solution derived from radial velocities in addition to Br-? line astrometry, which we show is more accurate than L' astrometry. We argue that although there is clearly gas associated with it, it seems more likely that the source is ultimately stellar in nature. Since in this case the potential impact on SgrA*'s accretion flow could be very subtle, we present a statistical analysis that can identify non-obvious variability state changes. This statistical framework has been taken from mathematical finance as is applied to light curves from the Galactic center black hole for the first time.

108.08 – VLT Observations of the Gas Cloud G2

Stefan Gillessen[1]
1. Max Planck Institute For Extraterrestrial Physics, Munich, Germany.

In 2011, we discovered a small, compact gas cloud G2 that is falling on a near-radial orbit toward the massive black hole in the Galactic Center. The orbit is well-constrained and the pericenter passage will occur in early 2014. Our data beautifully show that G2 gets tidally sheared apart due to the massive black hole's force. We expect that in addition to the tidal effects, hydrodynamics will become important when G2 collides with the hot ambient gas around Sgr A*. This might be a unique

opportunity in the next years to observe how gas feeds a massive black hole.

109 – Instrumentation I: Space Missions
Oral Session – Maryland 2 – 06 Jan 2014 10:00 am to 11:30 am

109.01 – Next Generation Submillimeter Heterodyne Focal Plane Array Technology

Paul Goldsmith[1], Imran Mehdi[1], Jonathan H. Kawamura[1], Jose V. Siles[1], Choonsup Lee[1], Goutam Chattoopadhyay[1], Bruce Bumble[1], Jeffrey A. Stern[1]
1. JPL, Pasadena, CA, United States.

The results from the Heterodyne Instrument for the Far Infrared (HIFI) on the Herschel Space Observatory have had a major impact on astronomy, including the first velocity-resolved survey of the critical 158 micron fine structure line of C+ to observations of water in comets. To follow up on Herschel's discoveries we need to be able to image significant areas with high angular resolution. This requires high-sensitivity focal plane heterodyne arrays, which is the driver for the present effort. The current state of the art for mixers at frequencies above ~1200 GHz utilizes Hot Electron Bolometer (HEB) mixers that have remarkably good sensitivity (noise temperature < 1000 K) and require low local oscillator power. One significant limitation is the IF bandwidth of < few GHz for NbN devices. At 2 THz, 1 GHz corresponds to a Doppler width of 150 km/s, less than seen in the 1900 GHz [CII] line. For higher frequency transitions, such as the [OI] fine structure line at 4.7 THz (63 micron wavelength), this bandwidth is insufficient. Development of new HEB materials such as magnesium based alloys may overcome this challenge, and promising results have been reported in the literature. A characteristic of all HEB mixers is their high sensitivity to local oscillator power variations. We have developed an architecture for array local oscillator power production and distribution that is based on a chain of multipliers starting from a Ka band source. Improved multiplier diodes as well as circuit designs have made it possible to obtain adequate LO power to 2.7 THz, with extension to 4.7 THz promising. We have developed a system design for a 1.9 THz [CII] array with a separate chain of multipliers for each pixel allowing individual control of LO power, together with efficient LO-signal combination in a single beamsplitter. We will present results from multiplier tests and results of measurements on a 4 pixel prototype of a full 16 or more pixel system. This robust and efficient approach is extendible to large-format arrays throughout the submillimeter.

109.02 – Technology Demonstration Milestone #1 for the EXoplanetary Circumstellar Environments and Disk Explorer (EXCEDE) I. Laboratory/Experimental Results.

Ruslan Belikov[1], Eduardo Bendek[1], Paul Davis[1], Alan Duncan[3], Thomas P. Greene[1], Olivier Guyon[2], Troy Hix[3], Wes Irwin[3], Rick Kendrick[3], Julien Lozi[2], Dana Lynch[1], Roger Mihara[3], Eugene Pluzhnik[1], Glenn Schneider[2], Eric Smith[3], Sandrine Thomas[1], Fred C. Witteborn[1]
1. NASA Ames Research Center, Moffett Field, CA, United States. 2. University of Arizona, Tucson, AZ, United States. 3. Lockheed Martin SSC, Palo Alto, CA, United States.

Coronagraph technology is advancing and promises to enable space telescopes capable of directly detecting and spatially resolving low surface brightness circumstellar debris disks as well as imaging giant planets as close as in the habitable zones of their host stars. One proposed mission capable of doing this is called EXCEDE (EXoplanetary Circumstellar Environments and Disk Explorer), which in 2011 was selected by NASA's Explorer program for technology development (Category III). EXCEDE is a 0.7m space telescope concept designed to achieve raw contrasts of 1e6 at an inner working angle of 1.2 l/D and 1e7 at 2 l/D and beyond. In addition to doing fundamental science on debris disks, EXCEDE will also serve as a technological and scientific precursor for an exo-Earth imaging mission. EXCEDE uses a Starlight Suppression System (SSS) based on the PIAA coronagraph, enabling aggressive performance. In this presentation, we report on our continuing progress of developing the SSS for EXCEDE, and in particular the achievement of the first major milestone in our technology development program (1e6 median raw contrast between a 1.2 l/D inner working angle and 2 l/D, simultaneously with 1e7 median raw contrast between 2 l/D and 4 l/D, in monochromatic light and in a controlled and repeatable fashion – see companion paper by Schneider et al. for science drivers). In addition, we will describe the upgrades to our system, such as (a) the Low Order Wavefront Sensor (LOWFS) which enabled achieving deep contrasts at aggressive inner working angles; (b) efficient model-based wavefront control algorithms; (c) a reconfiguration of our DM to be upstream of the coronagraph and the addition of the "inverse PIAA" system that enables better outer working angles. Finally, we report on preliminary demonstrations in a vacuum chamber. Even though this technology development is primarily targeted towards EXCEDE, it is also germane to any exoplanet direct imaging space-based telescopes because of the many challenges common to different coronagraph architectures and mission requirements. This work was supported in part by the NASA Explorer program and Ames Research Center, University of Arizona, and Lockheed Martin SSC.

109.03 – The Hybrid Lyot Coronagraph for the Imaging of Exoplanet Systems with the AFTA telescope

John T. Trauger[1], Brian Gordon[1], Dwight Moody[1]
1. JPL, Pasadena, CA, United States.

The WFIRST mission is evaluating the option of including an exoplanet coronagraphic camera to share the AFTA telescope focal plane with the primary wide field instrument. A hybrid Lyot coronagraph has been designed specifically for high contrast imaging of exoplanet systems with the AFTA telescope. This technique extends designs and extensive technology demonstrations for the hybrid Lyot coronagraph for unobscured space telescopes, but now modified to account for the complex pupil obscurations of the AFTA secondary mirror and support struts. The design provides contrast of a few times 10^-9, with 3 lambda/D inner working angle and 10% spectral bandwidth. We discuss the details of the design and its potential for breakthrough exoplanet science.

109.04 – Emulating Weak Gravitational Lensing Measurements in the Lab

Charles Shapiro[1]
1. JPL, California Institute of Technology, Pasadena, CA, United States.

"Weak" gravitational lensing refers to the way large-scale (extragalactic) gravitational fields slightly distort the observed shapes of galaxies. By averaging over many galaxy images, one can map gravitational fields and therefore the distribution of matter in the Universe, which is sensitive to the properties of dark matter and dark energy. As ongoing and future weak lensing missions create larger weak lensing maps, pushing galaxy counts from the millions into the billions, the drastically improved statistical power puts increasingly strict limits on the allowed galaxy shape measurement errors due to a telescope's detector (image sensor). In order to assess the impact of detectors on weak lensing measurements, Caltech and JPL have jointly formed the Precision Projector Lab (PPL). Our principal instrument – an Offner-based re-imaging system (a.k.a. "the projector") – casts precisely controlled images onto CCD, CMOS or IR detectors. Measuring these images allows us to characterize detectors and quantitatively understand their non-idealities. The projector can also emulate astronomical data such as stars, galaxies, or spectra in order to assess the impact of detector errors on real data. In this talk, I will briefly review weak gravitational lensing and then summarize our projector design and our analysis pipeline. I will present preliminary results from our investigation of a Teledyne Hawaii-2RG infrared detector similar to detectors planned for the Wide Field Infrared Survey Telescope (WFIRST). We place upper limits on shape correlation biases induced by the detector that are two orders of magnitude smaller than the expected gravitational signal from WFIRST.

109.05 – JPL Technology Development for the Dark Ages Radio Explorer (DARE) Proposal

Dayton L. Jones[1], Joseph Lazio[1], Mauricio Sanchez Barbetty[1], Deborah Sigel[1], Ian O'Dwyer[1]
1. JPL, Caltech, Pasadena, CA, United States.

In support of the Dark Ages Radio Explorer (DARE) proposal team, the Jet Propulsion Laboratory (JPL) has been investigating several technologies for this mission. The goal of DARE is to measure the sky-integrated spectrum of highly redshifted Hydrogen from the radio-quiet region above the far side of the Moon. The detailed shape of the spectrum in the 40-120 MHz region contains information on the epoch compact object formation and subsequent re-heating of the intergalactic medium. However, the expected Hydrogen signal strength is orders of magnitude weaker than the galactic foreground, and extreme instrumental stability and calibration accuracy will be needed to extract the signal of interest from the stronger foreground signal. JPL has developed a deployable bi-conical dipole antenna and measured its RF performance against a full-size, solid dipole to verify that the deployable concept will not compromise the spectral bandpass of the instrument. In addition, variations in bandpass response as a function of physical temperature of the front-end electronics (active balun and receiver) have been made over a wide temperature range. These data can be used to determine the required level of thermal control on the DARE spacecraft. This work has been carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. We also acknowledge support from the Lunar University Network for Astrophysical Research (LUNAR). The LUNAR consortium has been funded by the NASA Lunar Science Institute to investigate concepts for astrophysical observatories on the Moon via cooperative agreement NNA09DB30A.

109.06 – Chandra X-ray Observatory Pointing and its Stability

Ping Zhao[1]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.

Chandra X-ray Observatory is the only X-ray telescope achieving sub-arcsecond resolution. Its pointing stability is critical for achieving and retaining the unprecedented imaging quality. I will review the issues of telescope pointing stability, optical Axis, aimpoint, and evaluate the integrity and stability of the telescope.I will present data showing the drift of the Optical Axis and Aimpoint, their default offset, and explain their impacts to the Chandra operation. This study is essential to ensure the optimal operation of the Chandra X-ray Observatory.

109.07 – Starshade Alignment Sensing Demonstration Using Starlight

Ian J. Jordan[5, 1], Paul Henze[2, 7], Webster C. Cash[4], Michael W. Regan[6, 1], Mark Kochte[3], Remi

Soummer[1, 6], Curtis Roelle[7], Dorothy A. Fraquelli[5, 1], Peter C. Chen[9], Richard Lyon[8]
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Contributing teams: UMBRAS, WASI, New Worlds, JWST

From 2009-2013, our team designed, constructed, and operated a low-cost coelostat with COTS controller-software for use in demonstrating telescope-based alignment-sensing for an optically-scaled external occulter (starshade) plus telescope system. The system was tested and operated with various stellar sources in rural Maryland with baselines ranging from 10- to 93-metres (Fresnel-Numbers from 320 down to 18 at center-wavelengths 430-nm to 860-nm). The presentation describes technical challenges and solutions, and the current state of the data reduction.

109.08 – Uncertainties in the Astronomical Ephemeris as Constraints on New Physics
Zoey Warecki[1], James Overduin[1]
1. Towson University, Towson, MD, United States.

Most extensions of the standard model of particle physics predict composition-dependent violations of the universality of free fall (equivalence principle). We test this idea using observational uncertainties in mass, range and mean motion for the Moon and planets, as well as orbit uncertainties for Trojan asteroids and Saturnian satellites. For suitable pairs of solar-system bodies, we derive linearly independent constraints on relative difference in gravitational and inertial mass from modifications to Kepler's third law, the migration of stable Lagrange points, and orbital polarization (the Nordtvedt effect). These constraints can be combined with data on bulk composition to extract limits on violations of the equivalence principle for individual elements relative to one another. These limits are weaker than those from laboratory experiments, but span a much larger volume in composition space.

110 – Intergalactic Medium & QSO I
Oral Session – National Harbor 2 - 06 Jan 2014 10:00 am to 11:30 am

110.01D – OVI Absorbers Over Cosmic Time

Sowgat Muzahid[1, 2]

1. The Pennsylvania State University , State College , PA, United States. 2. Inter University Center for Astronomy & Astrophysics , Pune , Maharashtra, India.

OVI absorption is observed in a wide variety of astrophysical environments (e.g. IGM, CGM, local ISM, HVC, DLA etc.). The high cosmic abundance of oxygen, high ionization potential (IP = 113.9 eV) and high oscillator strength of OVI 1031,1037 doublets make the OVI transition a useful and well-studied tracer of diffuse and/or high temperature regions of the Universe. We have built a sample of intervening OVI absorbers in the Lyman-alpha forest of 18 high redshift ($z>2$) UV bright QSOs, observed with the VLT/UVES. This is the largest sample of high-z OVI absorber observed with a high resolution spectrograph. In this talk, the author will present various results related to the high redshift IGM as probed by OVI absorbers and compare them to low redshift IGM studies. The gas that lies in the immediate vicinity of galaxies (i.e. so called CGM gas), on the other hand, is of great interest to study the gas flows in galaxies. Tracing inflow/outflow is essential for understanding formation and evolution of galaxies. In the last part of the talk, the author will highlight some of his recent studies on intermediate redshift ($0.4 < z < 1.0$) OVI absorption in MgII selected absorbers, which presumably trace the CGM environment.

110.02 – The CGM around dwarf galaxies

Rongmon Bordoloi[1], Jason Tumlinson[1], Jessica Werk[2], Christopher Thom[1], Jason X. Prochaska[2], Todd M. Tripp[3], Neal Katz[3], Romeel Dave[4, 5], Benjamin Oppenheimer[6, 7], Amanda Brady Ford[4], John M. O'Meara[8], Molly S. Peeples[1, 9], Kenneth Sembach[1], David H. Weinberg[10]

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I will present the first results mapping the 2-D distribution of circumgalactic gas around nearby dwarf galaxies from the COS-Dwarfs survey. COS-Dwarfs survey uses HST/COS spectroscopy to probe the halos of low redshift galaxies with luminosities $L = (0.02 - 0.3)L^*$, stellar masses $(M_*) = 10^{(8-10)} M_{sun}$, up to impact parameters of 150 kpc. Using sensitive UV absorption-line measurements of the multiphase gas diagnostics such as Lyα, CII/IV, Si II/III/IV I will present the radial and azimuthal distribution of such gas around these galaxies. I will also show how the absorption strengths vary with host galaxy color, mass, star formation rate, orientation, and how they compare with that of the L* galaxies probed by our related COS-Halos survey. In particular, I will present the dependence of CIV absorption on specific star formation rate (sSFR) and a total mass estimate for carbon around these dwarf galaxies.

110.03 – OVI as an Unique Tracer of Large-Scale Stellar Feedback at 2<z<4.

Nicolas Lehner[1], John O'Meara[2], Vincent Burns[1], J. C. Howk[1], Jason X. Prochaska[3], Andrew Fox[4], Ashley Armstrong[2], Arthur M. Wolfe[5]

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We review the first results from our large KODIAQ (Keck Observatory Database of Ionized Absorbers toward Quasars) survey that aims to characterize the properties of the OVI-bearing gas associated with optically thick absorbers (Lyman limit systems and Damped Lya absorbers, LLSs and DLAs) at z>2. We searched the Keck observatory archive (KOA) for optically thick HI absorbers where the OVI doublet has little contamination and where the HI column density and the metallicity can be estimated to study the OVI properties, and baryon and metal budgets in the highly ionized phase as a function of these parameters. We assembled a sample of 20 absorbers that satisfy these criteria. Based on the comparison of the absorption profiles of the high ions (OVI, NV, CIV, SiIV), we show that the physics that govern the O VI and the other high ions are

generally quite different, implying that the highly ionized gas in LLSs and DLAs is multiphase. All the properties of the OVI absorption imply that the OVI-bearing gas is not in collisional ionization equilibrium, but seems instead consistent with radiatively cooling flows of hot gas. The observed high OVI columns are also consistent with those seen in local starburst galaxies, making OVI associated with LLSs and DLAs a potential unique tracer of stellar activity on large scales at z>2.

110.04D – Study of Chemical Evolution in Sub-damped Lyman-alpha QSO Absorbers

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We present chemical abundance measurements of sub-Damped Lyman-alpha QSO absorbers at redshifts z < 0.6 and z > 2.0, observed with the High Dispersion Spectrograph (HDS) on the Subaru Telescope and the Magellan Inamori Kyocera Echelle (MIKE) spectrograph on the Magellan II Clay Telescope, respectively. Our data include absorption lines from several elements in various ionization stages such as Mg I, Mg II, Al II, Al III, Si II, Si III, Si IV, S II, Mn II, Ni II, Cr II, Ti II, C II, C II*, C IV, and Zn II. The metallicities of the absorbers were inferred from the nearly undepleted elements Zn and S, and ionization corrections, if necessary, were applied. Combining our data with the literature sample, we present the most complete existing determination of the metallicity vs. redshift relation for sub-DLAs and DLAs. We confirm the suggestion from previous investigations that sub-DLA absorbers are, on average, more metal rich than DLAs and evolve faster. We also discuss the relative abundances (i. e [Zn/Fe], [Mn/Fe]) seen in the absorbers in this sample. We use the velocity width values for these sub-DLAs, as inferred from unsaturated metal absorption lines, to explore the velocity width vs. metallicity relation in sub-DLAs. We also report the first estimates of cooling rates in sub-DLA quasar absorbers based on the CII* column density measurements from our sample.

110.05 – A Detailed Spatial Study of HI and OVI Absorbing Gas Around Galaxies

Nigel Mathes[1], Christopher W. Churchill[1], Glenn Kacprzak[2], Nikole M. Nielsen[1], Jane C. Charlton[3], Sowgat Muzahid[3]
1. New Mexico State University, Las Cruces, NM, United States. 2. Swinburne University of Technology, Hawthorn, VIC, Australia. 3. The Pennsylvania State University, University Park, PA, United States.

Neutral hydrogen probed by the Lyα transition in quasar absorption spectra traces the circumgalactic and intergalactic medium (CGM and IGM) of distant galaxies. The exact phase and composition of the gas associated with each region along with the spatial boundary separating the two has yet to be specifically characterized. To probe this region, we present a sample of 17 isolated galaxies with high resolution Hubble Space Telescope images and spectra lying within 400 kpc of a quasar line of sight between redshfits 0.1 < z < 0.7. We model each associated absorption system using a Voigt Profile fitting method for Lyα, Lyβ and OVI, which yields column densities, Doppler b parameters, and velocities for each cloud. We also model each galaxy to obtain its orientation on the sky and employ Halo Abundance Matching to determine the galaxy mass and virial radius. In contrast to previous studies using MgII absorbers, we find a near uniform distribution of absorbing gas clouds at all projected angles around the galaxies. We also find Lyα absorbing clouds out to impact parameters of 300 kpc and OVI absorbers out to 250 kpc. Together, this implies an extended, warm gas halo surrounding the galaxies in our sample. To better characterize these halos and to study the boundary between the CGM and IGM, we explore column densities and kinematics at different impact parameters. We find all Lyα systems with column densities higher than the sample average $(\log N(HI) > 15 \text{ cm}^{-2})$ are located within the virial radius of their associated galaxies. We also find that kinematically unbound clouds are more likely to be found outside the virial radius (46% of clouds outside the virial radius have velocities in excess of the galaxy escape velocity, whereas only 10% of clouds within the virial radius have velocities high enough to escape). No such boundary exists when considering only physical impact parameters. We observe a distinct physical difference between gas inside and outside of a galaxy's virial radius, signalling that galaxy mass may hold the key to determining the spatial extent and overall characteristics of the CGM.

110.06 – Tracing the flow of gas onto galaxies with the Green Bank Telescope

Daniel J. Pisano[1,2], Katherine Rabidoux[1], Willem J.G. de Blok[4], Adam K. Leroy[3], Fabian Walter[5], Frank Bigiel[6], Elias Brinks[8], Katie M. Keating[7]
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Astronomie, Heidelberg, Germany. 6. University of Heidelberg, Heidelberg, Germany. 7. Rincon Research Corporation, Tucson, AZ, United States. 8. University of Hertfordshire, Hertfordshire, United Kingdom.

One of the key questions in astronomy today is how galaxies accrete their gas and then convert that gas into stars. The HI Nearby Galaxies Survey (THINGS), conducted with the VLA, has made great strides towards answering these questions, but it lacked sensitivity to the extended, diffuse HI in and around galaxies. To rectify this problem, my collaborators and I have recently completed a Green Bank Telescope (GBT) HI survey of the THINGS galaxies. The GBT's clean beam, low system temperature and good angular resolution make it the ideal single-dish telescope for observing low column density HI. Our survey was capable of detecting HI emission from analogs to Lyman limit systems, provided it fills the GBT beam. I will present the first results from our search for low column density tidal features and infall from the ``cosmic web", and I will detail my future plans.

111 – Interstellar Medium & Dust I
Oral Session – National Harbor 4 – 06 Jan 2014 10:00 am to 11:30 am

111.01 – Modeling Thermal Dust Emission and Implications

Zhuohan Liang[1]
1. Loyola University Maryland, Baltimore, MD, United States.

An accurate model of thermal dust emission at the far-infrared and millimeter wavelengths is important for studying the cosmic microwave background anisotropies and for understanding the cycling of matter and energy between stars and the interstellar medium. I will present results of fitting all-sky one-component dust models with fixed or variable emissivity spectral index to the 210-channel dust spectra from the COBE-FIRAS, the 100 240 μm maps from the COBE-DIRBE, and the 94 GHz dust map from the WMAP. I will also discuss the implications of the analysis on understanding astrophysical processes and the physical properties of dust grains.

111.02 – X-ray Studies of Interstellar and Intergalactic Dust

Lia Corrales[1], Frits B. Paerels[1]
1. Columbia University, New York, NY, United States.

Dust grain composition, sizes, and spatial distribution can be directly measured with high resolution X-ray imaging and spectroscopy. Dust in the foreground of bright point sources will scatter X-rays through small angles, producing a diffuse `halo' image. The scattering cross-section is most sensitive to large dust grains, which are typically missed in UV, optical, and infrared studies. The dust-to-gas mass ratio and elemental constituents of dust grains can also be determined from X-ray spectroscopy. I demonstrate how a Bayesian analysis of the scattering halo around Cyg X-3 yields a grain size distribution and mass ratio that does not match properties typically assumed of Galactic dust. Finally, I will discuss the prospects for using quasars to measure the cosmic density of dust grains in intergalactic space.

111.03 – Dust Lifetimes and Grain Destruction Rates by Supernova Remnants in the Magellanic Clouds

Tea Temim[1, 2], Eli Dwek[1], Margaret Meixner[3], Martha L. Boyer[1, 2], Kirill Tchernyshyov[4], Christa Gall[5]
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The presence of dust in galaxies has a profound effect on their spectral appearance and on the many processes that determine the physical, chemical, and thermal state of their interstellar medium (ISM). Despite the many different manifestation of interstellar dust in the Milky Way and external galaxies, its nature, origin, and evolution are still poorly understood. The understanding of the dust destruction rates by supernova shocks in particular is extremely important for understanding its origin. The amount of grain destruction determines whether the dust budget can be balanced by dust formation in stellar sources, or whether dust growth in molecular clouds is required. Due to their extensive wavelength coverage and known distance, the Magellanic Clouds offer a unique opportunity for studying dust destruction rates and lifetimes in the ISM. I will present new estimates of dust destruction rates by supernova remnants in the Magellanic Clouds and discuss their implications for dust evolution models.

111.04 – THE EVOLUTION OF DUST IN THE MAGELLANIC CLOUDS

Eli Dwek[1], Tea Temim[1, 2], Margaret Meixner[3], Martha L. Boyer[1, 2], Kirill Tchernyshyov[4], Christa Gall[1, 5]
1. Observational Cosmology Lab, Code 665, NASA GSFC, Greenbelt, MD, United States. 2. Oak Ridge Associated Universities (ORAU), Oak Ridge, TN, United States. 3. Space Telescope Science Institute (STScI), Baltimore, MD, United States. 4. Johns Hopkins University, Baltimore, MD, United States. 5. Aarhus University, Aurhus, Denmark.

The Magellanic Clouds offer a unique astrophysical laboratory for studying the evolution of interstellar dust. They are the closest to the Milky Way with well determined distance, and they have been extensively studies at many different wavelength with sufficient spatial resolution to construct a detailed picture of the evolution of the dust in the diverse stellar and interstellar environments of these two galaxies. Using chemical evolution models for the dust I will present the formation rates of the dust in AGB stars and supernovae, and compare them to observations. The dust formation rates will then be

compared to their observed rates of destruction by supernova remnants (see Temim, this meeting). The comparison will provide important information on the origin of dust in the Magellanic Clouds. Understanding the different stellar sources of dust and the processes leading to their destruction are essential for understanding the origin of dust in the Milky Way, in local galaxies, and the early universe as well.

111.05 – Power-law Temperature Distribution SED Modeling To Reveal Properties of High-z Starburst Galaxies

Ting Su[1], Johannes Staguhn[1, 2], Eli Dwek[2], Attila Kovacs[3, 4]
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Sub-millimeter galaxies (SMGs), selected as the most luminous sources in submm/mm surveys in recent decades, are a group of highly dust-obscured massive galaxies at high redshifts energized by starbursts. SMG surveys enable us to study the nature of those sources in detail. Previous samples of SMGs are typically distributed at z ? 0.53. In order to explore the evolutionary properties of SMGs up to an earlier epoch, we present a sample of 12 sources at average z ? 4. Five of our sources are from the GISMO 2mm Deep Field survey–the very first 2mm deep field survey, which favors higher redshift sources with its superior sensitivity and relatively longer wavelength. The other seven are extremely high redshift SMGs (z > 4) including six from Michalowski et al. 2010b and one at z=5.3 from Dwek et al. 2011. Since rest frame far-infrared continuum dust emission is the best tracer of star-formation activities to date, we employ a power-law temperature distribution SED model to analyze the data. This model which fits for dust grains embedded in a radiation field, allows for different dust compositions, size distribution, and emission region geometry. Our fit results represent the data very accurately even in the Wien part of the SED. Our analysis shows that the SED is not optically thin around the SED peak, as is often assumed. In my talk I will present source fitting results of dust mass, dust temperature, index of temperature power-law distribution, and emission region size. Furthermore, I will analyze the evolutionary trends of SMGs properties with redshift and discuss astrophysical implications for those results.

111.06 – Relations between mid-IR dust emission and UV extinction

Derck Massa[1], Edward L. Fitzpatrick[3], Karl D. Gordon[2]
1. Space Science Institute, Boulder, CO, United States. 2. STScI, Baltimore, MD, United States. 3. Villanova University, Villanova, PA, United States.

We present a comparison of Spitzer mid-IR emission spectral features and UV extinction properties for sight lines to stars at high Galactic latitude which lie beyond the bulk of the Milky Way dust layer. For these sight lines the emission and extinction sample the same dust. The dust emission is described by the Draine & Li (2007) PAH model with the addition of a continuum component which removes residual Zodiacal light contributions. The derived emission parameters are compared to the different Fitzpatrick & Massa (1990) parameters which describe the shapes of UV extinction curves. Results from this comparison will be discussed.

112 – Nearby Dwarf & Irregular Galaxies
Oral Session – Maryland Ballroom D – 06 Jan 2014 10:00 am to 11:30 am

112.01 – Andromeda's dwarf spheroidals and the universal mass profile

Michelle Collins[1], Robert M. Rich[2], Nicolas Martin[3], Rodrigo Ibata[3], Scott C. Chapman[4], Alan W. McConnachie[5]
1. MPIA, Heidelberg, b.Munchen, Germany, Germany. 2. UCLA, Los Angeles, CA, United States. 3. Strasbourg Observatory, Strasbourg, France. 4. Dalhousie, Halifax, NS, Canada. 5. HIA, Victoria, BC, Canada.
Contributing teams: PAndAS

As the faintest, least massive galaxies we are able to observe, dwarf spheroidal galaxies represent the fundamental galactic unit. Their study in the Milky Way has led to several interesting findings and are helping us to better understand the behaviour of dark matter on the smallest scales. In this talk, I will present work from the ongoing PAndAS spectroscopic follow up survey of Andromeda, focusing on our results for its dwarf galaxy population. I will show that by including the masses measured for these objects in our analysis of the mass profiles of all dwarf galaxies, we are able to demonstrate that the notion of a universal mass profile for these most minute of galaxies is false. I will also identify several interesting objects whose properties defy our expectations, and discuss what these mean for our understanding of the physics governing galactic evolution.

112.02D – Variations in a Universal Density Profile for the Milky Way's Dwarf Spheroidal Galaxies

John Jardel[1], Karl Gebhardt[1]
1. The University of Texas, Austin, TX, United States.

On the largest scales, the Cold Dark Matter (CDM) paradigm for structure formation has enjoyed remarkable success in describing the universe we live in. The current frontier in our knowledge of galaxy formation is at the low-mass level. Here we find disagreement between theory and observations in a number of interesting cases. One such problem that has received considerable attention is the debate over the shape of the dark matter density profiles in the Milky Way's dwarf spheroidal (dSph) galaxies, known as the core/cusp problem. CDM simulations predict every halo should have a cuspy profile with an inner logarithmic slope of -1, but some observers have found that profiles with constant density inner cores are preferred. However, a major weakness of this previous work is that the dynamical models constructed to measure the mass distribution have had to assume a parameterization for the dark matter profile--exactly the thing one wishes to measure. For my thesis I introduced a new modeling technique, based on Schwarzschild's method, that instead calculates the dark matter profile non-parametrically. Applying these models to five of the Milky Way's dSphs I found a variety of profile shapes including cores, cusps, and other completely unexpected shapes. When scaled to a common normalization, however, I found the combined profile appears to follow an approximate power law with slope -1. The results of this averaging suggest that the individual formation histories of each galaxy produce differing dark matter profiles, but with a net result that is similar to CDM predictions. To better understand the role baryons play in this process, I compare my results to recent hydrodynamical simulations of the formation of dwarf galaxies. Together, my results and the simulations suggest a trend of flatter profiles in galaxies where more stars have formed. This implies that star formation and dark matter halos are linked through the effects of supernova-induced outflows which are more prominent in galaxies that have formed more stars.

112.03 – Massive No More: How baryon removal and tidal stripping alter the structure of dwarf spheroidal galaxies

Kenza S. Arraki[1], Anatoly A. Klypin[1], Surhud More[2], Sebastian Trujillo-Gomez[1]
1. New Mexico State University, Las Cruces, NM, United States. 2. Kavli Institute for the Physics and Mathematics of the Universe (WPI), University of Tokyo, Kashiwa, Chiba, Japan.

The Cold Dark Matter (CDM) cosmological model makes very specific predictions about the growth and formation of structure. When comparing these theoretical predictions to observations it is typical to employ collisionless cosmological N-body simulations. However, as we examine smaller, galactic scales, it requires an understanding of the limitations of these simulations before we claim discrepancies with the observed universe. We examine how baryons influence galactic evolution at the small scale of dwarf spheroidal (dSph) galaxies. Collisionless cosmological N-body simulations assume that the baryon fraction everywhere in the Universe is equal to the cosmic mean, an assumption that is incorrect for dSphs. We find that the combination of (i) the lower baryon fraction in dSphs compared to the cosmic mean and (ii) the concentration of baryons in the inner part of the MW halo can go a long way towards explaining the observed circular velocity profiles of present day dSphs. In order to investigate this, we perform numerical simulations that mimic the effects of baryons. We create present day dSphs with low baryon fractions by removing the baryonic component from their progenitors, reducing the final inner densities by 30 to 50%. The density in the central ~500 pc is reduced by a factor of $(1 - f\_b)^4 \sim 0.5$, where f_b is the

cosmological fraction of baryons. Additionally, increasing the central baryonic mass of the host galaxy generates larger tidal forces than in traditional N-body simulations. Both of these effects reduce the density and circular velocity profiles of satellite galaxies. Together they can bring collisionless simulations into agreement with the observed structure of MW dSphs, regardless of the details of the baryonic processes.

112.04D – Observational Constraints on Models of Rapidly Evolving Luminous Stars

Philip Rosenfield[1,2], Julianne Dalcanton[1], Leo Girardi[3], Paola Marigo[2], Alessandro Bressan[4]
1. University of Washington, Seattle, WA, United States. 2. Dipartimento di Fisica e Astronomia 'Galileo Galilei', Padova, PD, Italy. 3. INAF-OAPd, Padova, PD, Italy. 4. SISSA, Trieste, Italy.
Contributing teams: ANGST Team

Resolved stellar populations in galaxies are excellent laboratories for testing our understanding of galaxy formation, integrated colors and luminosities, supernova progenitor masses, and energy input from stellar feedback. However, the usefulness of resolved stellar populations rests on the ability to accurately model the evolution of the underlying stars. Part of my thesis work is focused on two uncertain phases of stellar evolution; the luminous core helium burning (HeB) phase and the thermally pulsating AGB (TP-AGB) phase. Dwarf galaxies, imaged as part of the ACS Nearby Galaxy Survey Treasury and its HST/NIR follow-up campaign, provide ideal testing grounds for new models because the galaxies span ~2 dex in metallicity, many have significant HeB populations (i.e, the HeB sequence is populated with stars with masses from ~2-15 Msun), and many contain large numbers of TP-AGB stars. I will present how I used ANGST to constrain low metallicity stellar evolution models with the Padova-Trieste Stellar Evolution Code (PARSEC; the recently updated Padova Stellar Evolution Library) and COLIBRI (a new tool for modeling TP-AGB stars). Specifically, I will show how increasing the strength of core overshooting with increasing mass in HeB stars improves data and model agreement. I will also present constraints to the mass loss prescriptions of low mass, low metallicity TP-AGB stars.

112.05 – Ultra-Deep HST Imaging of the SMC: The IMF at M < 1 Msun

Jason S. Kalirai[1,2], Jay Anderson[1], Aaron L. Dotter[1], Harvey B. Richer[3], Gregory G. Fahlman[4], Bradley M. Hansen[5], Jarrod R. Hurley[6], Iain N. Reid[1], Robert M. Rich[5], Michael Shara[7]
1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Johns Hopkins University, Center for Astrophysical Sciences, Baltimore, MD, United States. 3. University of British COlumbia, Vancouver, BC, Canada. 4. NRC/HIA, Victoria, BC, Canada. 5. UCLA, Los Angeles, CA, United States. 6. Swinburne University of Technology, Melbourne, VIC, Australia. 7. American Museum of Natural History, New York, NY, United States.

We present a new measurement of the stellar Initial Mass Function (IMF) based on ultra-deep, high-resolution photometry of >5,000 stars in the outskirts of the Small Magellanic Cloud (SMC) galaxy. The stellar main sequence of the SMC is measured in the color-magnitude diagram (CMD) down to ~30th magnitude, and is cleanly separated from the foreground star cluster population using proper motions. We simulate the SMC population by extracting stellar masses (single and unresolved binaries) from specific IMFs, and converting those masses to luminosities in our bandpasses. The corresponding photometry for these simulated stars is drawn directly from a rich cloud of 4~million artificial stars, thereby accounting for the real photometric scatter and completeness of the data. Over a continuous and well populated mass range of M = 0.37-0.93 Msun, we demonstrate that the IMF is well represented by a single power-law form with slope \alpha = -1.90 ([+0.15] [-0.10]) (3 \sigma error) (i.e., dN/dM propto M^(\alpha), Salpeter \alpha = -2.35). Our results indicate that the IMF does not turn over to a more shallow power law form within this mass range.

112.06 – The Effect of Metallicity on Molecular Gas and Star Formation in the Large Magellanic Cloud

Katherine Jameson[1], Alberto D. Bolatto[1], Adam K. Leroy[2], Mark G. Wolfire[1], Margaret Meixner[3], Julia Roman-Duval[3], Karl D. Gordon[3]
1. University of Maryland, College Park, MD, United States. 2. NRAO, Charlottesville, VA, United States. 3. STScI, Baltimore, MD, United States.
Contributing teams: HERITAGE Collaboration

The Magellanic Clouds provide the only laboratory to study the effect of metallicity on molecular gas and star formation at high resolution. We use the dust emission (Herschel 100, 160, 250, and 350 micron) to trace the total column of gas distribution and remove the HI gas leaving the molecular gas component distribution; we avoid the known biases of CO and reveal molecular gas with no bright CO emission. Relating the molecular gas to the star formation rate, traced by H-alpha and 24 micron, reveals an average molecular gas depletion time of ? 1 Gyr in the LMC. This is consistent with normal disk galaxies (? 2 Gyr; Bigiel et al. 2008, 2012) and the SMC (Bolatto et al. 2011), suggesting that metallicity does not strongly

affect the galaxy-wide molecular gas star formation efficiency. We also contrast the metallicity-dependent predictions of the Ostriker, McKee, & Leroy (2011) and Krumholz, McKee, & Tumlinson (2009) models of star formation with the data.

112.07 – Evidence for an Interaction in the Nearest Starbursing Dwarf Galaxy IC 10

David L. Nidever[1,2], Trisha L. Ashley[3], Colin Slater[1], Juergen Ott[4], Megan C. Johnson[5], Eric F. Bell[1], Snezana Stanimirovic[6], Mary E. Putman[7], Steven Majewski[2], Caroline E. Simpson[3], W. Butler Burton[8], Eva Juette[9], Tom Oosterloo[10]

1. University of Michigan, Ann Arbor, MI, United States. 2. University of Virginia, Charlottesville, VA, United States. 3. Florida International University, Miami, FL, United States. 4. National Radio Astronomy Observatory, Socorro, NM, United States. 5. National Radio Astronomy Observatory, Green Bank, WV, United States. 6. University of Wisconsin, Madison, WI, United States. 7. Columbia University, New York, NY, United States. 8. National Radio Astronomy Observatory, Charlottesville, VA, United States. 9. Ruhr-Universitaet Bochum, Bochum, North Rhine-Westphalia, Germany. 10. Netherlands Institute for Radio Astronomy, Dwingeloo, Drenthe, Netherlands.

Using deep 21-cm HI data from the Green Bank Telescope we have detected an ~18.3 kpc-long gaseous extension associated with the starbursting dwarf galaxy IC 10. The newly-found feature stretches 1.3 deg to the northwest and has a large radial velocity gradient reaching to ~65 km/s lower than the IC 10 systemic velocity. A region of higher column density at the end of the extension that possesses a coherent velocity gradient (~10 km/s across ~26 arcmin) transverse to the extension suggests rotation and may be a satellite galaxy of IC 10. The HI mass of IC 10 is 9.5x10^7 (d/805 kpc)^2 Msun and the mass of the new extension is 7.1x10^5 (d/805 kpc)^2 Msun. An IC 10-M31 orbit using known radial velocity and proper motion values for IC 10 show that the HI extension is inconsistent with the trailing portion of the orbit so that an M31-tidal or ram pressure origin seems unlikely. We argue that the most plausible explanation for the new feature is that it is the result of a recent interaction (and possible late merger) with another dwarf galaxy. This interaction could not only have triggered the origin of the recent starburst in IC 10, but could also explain the existence of previously-found counter-rotating HI gas in the periphery of the IC 10 which was interpreted as originating from primordial gas infall.

113 – Novae, Dwarf Novae and Evolved Stars

Oral Session – Maryland 1 – 06 Jan 2014 10:00 am to 11:30 am

113.01 – Fermi Discovers a New Population of Gamma-ray Novae

Chi C. Cheung[1], Steve N. Shore[2,3], Pierre Jean[4]
1. NRL, Washington, DC, United States. 2. University of Pisa, Pisa, Italy. 3. INFN, Pisa, Italy. 4. IRAP, Toulouse, France.
Contributing teams: on behalf of the Fermi-LAT collaboration

Classical novae were not widely expected to be high-energy (>100 MeV) gamma-ray sources prior to the launch of the Fermi Gamma-ray Space Telescope. In March 2010, the Fermi Large Area Telescope (LAT) made the first gamma-ray detection of a nova, in the symbiotic binary V407 Cygni. The LAT observations uniquely revealed high-energy particle acceleration in the circumstellar environment of the V407 Cyg recurrent binary system consisting of a white dwarf and Mira variable companion. Subsequently three classical novae have been detected by the LAT, Nova Sco 2012, V959 Monocerotis 2012, and V339 Delphini 2013, thus heralding novae as a new gamma-ray source class. For V959 Mon 2012, the gamma-ray transient source was discovered before the optical confirmation of the nova. This showcases the all-sky monitoring capability of the LAT, and how novae can be found independently from traditional optical searches. The most recent LAT detection of V339 Del 2013 was made possible through a Fermi Target of Opportunity observation triggered on the bright optical nova discovery. We discuss the LAT detected gamma-ray novae together with observational limits on other recent Galactic novae and discuss their possible high-energy gamma-ray production mechanisms in light of the new detections.

113.02 – Radio Observations of Gamma-ray Novae

Justin D. Linford[1], Laura Chomiuk[1], Valerio Ribeiro[2]
1. Michigan State University, East Lansing, MI, United States. 2. University of Cape Town, Cape Town, South Africa.
Contributing teams: E-Nova project

Recent detection of gamma-ray emission from classical novae by the Large Area Telescope (LAT) on board the Fermi Gamma-ray Space Telescope surprised many in the astronomical community. We present results from radio observations, obtained using the Karl G. Jansky Very Large Array (VLA), of three gamma-ray novae: Mon2012, Sco2012, and Del2013. Radio observations allow for the calculation of ejecta masses, place limits on the distances, and provide information about the gamma-ray emission mechanism for these sources.

113.03 – The Effect of Globular Cluster Specific Frequency on the Relative Nova Rates in Three Virgo Elliptical Galaxies

Christopher Curtin[1], Allen W. Shafter[1], Christopher Pritchet[2]
1. San Diego State University, San Diego, CA, United States. 2. University of Victoria, Victoria, BC, Canada.

The discrepancy between predicted and observed luminosity-specific nova rates from different stellar populations may result in part from competing nova formation mechanisms. Population synthesis models predict higher relative nova rates in young disk populations compared with older bulge populations. However, observations suggest that novae may occur more frequently in bulge populations. Recognizing this discrepancy, Ciardullo et al. (1987, ApJ, 318, 520) proposed that a significant percentage of a galaxy's nova progenitors might be spawned in globular clusters and later injected into the bulge rather than formed through common-envelope evolution. In 2011 we proposed a simple and direct observational test of this hypothesis. Three galaxies, M87, M49 and M84, of comparable luminosity and distance, but with significantly different globular cluster specific frequencies, SN=14,3.6,1.6 respectively, were observed under identical conditions in 4 epochs over 14 months in order to compare their relative nova rates. Preliminary results from this study were presented in Shafter et al. (2013, AAS Meeting #221, #148.06). Under the null hypothesis that the nova rate per unit luminosity is independent of SN, the numbers of novae per galaxy were expected to be ~22/32/15, respectively. Under the hypothesis that nova rates are dependent on SN, the relative numbers could be as different as ~86/32/7, respectively, in the extreme case where all novae are formed in clusters. Upon reduction of the entire data set we found 23/27/19 novae per galaxy respectively, with overall nova rates yet to be determined. The results of our study establish that the percentage of nova progenitors formed in globular clusters is not large enough to significantly affect a galaxy's observed nova rate.

113.04 – Dwarf Novae in the Galactic Bulge Survey - Observational Constraints on X-ray/Recurrence Time Relations and Space Density.

Christopher Britt[1,2], Thomas J. Maccarone[1], Robert I. Hynes[2], Peter Jonker[3,4], Manuel Torres[3,4]
1. Texas Tech University, Lubbock, TX, United States. 2. Lousiana State University, Baton Rouge, LA,

United States. 3. SRON Netherlands Institute for Space Research, Utrecht, Utrecht, Netherlands. 4. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.
Contributing teams: Galactic Bulge Survey Collaboration

The Galactic Bulge Survey is a shallow, wide-field X-ray survey of the Galactic Bulge made with the Chandra X-ray Observatory, covering 12 square degrees above and below the Galactic Plane, centered at |b|=1.5°. In 8 days of optical observations, made with the Mosaic-II instrument on the Blanco 4m telescope at CTIO with the purpose of identifying variable optical counterparts to the 1216 unique X-ray sources in the GBS, 8 dwarf novae (DN) outbursts were identified. 4 of the X-ray detected systems undergoing DN outbursts are within the 100 brightest X-ray sources. It is thought that X-ray flux in DN systems traces mass accretion, which is correlated with recurrence rate. With these observations, we can place observational constraints on the relationship between X-ray flux and recurrence rates. In addition, there are DN outbursts in our data set for which no X-ray detection was made. We can use our observations to independently estimate the space density of systems undergoing DN outbursts in the Milky Way.

113.05 – Spitzer-IRS Spectroscopic Studies of the Properties of Dust from Oxygen-Rich Asymptotic Giant Branch and Red Supergiant Stars

Benjamin A. Sargent[1], Angela Speck[2], Kevin Volk[3], Ciska Kemper[4], William T. Reach[5], Eric Lagadec[6], Jean-Philippe Bernard[7,8], Iain McDonald[9], Margaret Meixner[3], Sundar Srinivasan[4]
1. Rochester Institute of Technology, Rochester, NY, United States. 2. University of Missouri, Columbia, MO, United States. 3. Space Telescope Science Institute, Baltimore, MD, United States. 4. Academia Sinica, Institute of Astronomy and Astrophysics, Taipei, Taiwan. 5. Stratospheric Observatory for Infrared Astronomy, Universities Space Research Association, Moffett Field, CA, United States. 6. Cornell University, Ithaca, NY, United States. 7. CNRS, IRAP, Toulouse, France. 8. Universite de Toulouse, Toulouse, France. 9. University of Manchester, Jodrell Bank Centre for Astrophysics, Manchester, United Kingdom.

We analyze the dust emission features seen in Spitzer Space Telescope Infrared Spectrograph (IRS) spectra of Oxygen-rich (O-rich) asymptotic giant branch (AGB) and red supergiant (RSG) stars. The spectra come from the Spitzer Legacy program SAGE-Spectroscopy (PI: F. Kemper) and other archival Spitzer-IRS programs. The broad 10 and 20 micron emission features attributed to amorphous dust of silicate composition seen in the spectra show evidence for systematic differences in the centroid of both emission features between O-rich AGB and RSG populations. Radiative transfer modeling using the GRAMS grid of models of AGB and RSG stars suggests that the centroid differences are due to differences in dust properties. We investigate differences in dust composition, size, shape, etc that might be responsible for these spectral differences. We explore how these differences may arise from the different circumstellar environments around RSG and O-rich AGB stars. BAS acknowledges funding from NASA ADAP grant NNX13AD54G.

113.06 – A Search for Thorne-Zytkow Objects

Emily M. Levesque[1], Philip Massey[2], Nidia Morrell[3], Anna Zytkow[4]
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Thorne-Zytkow objects (TZOs) are a theoretical class of star in which a compact neutron star is surrounded by a large, diffuse envelope. Supergiant TZOs are predicted to be almost identical in appearance to red supergiants (RSGs), with their very red colors and cool temperatures placing them at the Hayashi limit on the H-R diagram. The best features that can be used at present to distinguish TZOs from the general RSG population are the unusually strong heavy-element lines present in their spectra. These elements are the unique products of the star's fully convective envelope linking the photosphere with the extraordinarily hot burning region in the vicinity of the neutron star core. The positive detection of a TZO would provide the first direct evidence for a completely new model of stellar interiors, a theoretically predicted fate for massive binary systems, and never-before-seen nucleosynthesis processes that would offer a new channel for heavy-element production in our universe. We recently conducted a high-resolution spectroscopic search for TZOs within our previously-studied samples of RSGs in the Milky Way and Magellanic Clouds. Did we find any? We'll know soon! Come to this talk and find out!

114 – Pulsars & Neutron Stars I

Oral Session – National Harbor 13 – 06 Jan 2014 10:00 am to 11:30 am

114.01 – Latest NANOGrav Pulsar Timing Results: Toward the Detection of Gravitational Waves

Paul Demorest[1]
1. National Radio Astronomy Observatory, Charlottesville, VA, United States.
Contributing teams: NANOGrav Collaboration

The North American Nanohertz Observatory for Gravitational Waves (NANOGrav) project has been monitoring a set of millisecond pulsars using the Green Bank and Arecibo radio telescopes since 2005. The goal of this long-term pulsar timing project is the direct detection of nHz-frequency gravitational radiation, which induces tiny fluctuations in the measured radio pulse times of arrival. Between 2010 and 2012 upgraded instrumentation was developed and installed at both telescopes -- this provided an order-of-magnitude increase in the recorded radio bandwidth, which results in dramatic improvement to both pulse signal-to-noise ratio and our ability to measure wavelength-dependent timing effects such as interstellar dispersion. Over the same timeframe, the number of pulsars monitored has more than doubled, from 17 at the start of the project to 42 currently. Here we present an overview of the current NANOGrav data set, with special focus on the improved timing results now coming from the post-upgrade instrumentation. We will discuss several new data analysis methods developed to handle wide-band, multi-instrument timing data sets; improved measurements of pulsar timing parameters resulting from these observations; and the predicted improvement in future gravitational wave sensitivity.

114.02 – Monitoring the interstellar scattering delays of NANOGrav millisecond pulsars

Lina Levin Preston[1], James M. Cordes[2], Paul Demorest[3], Timothy Dolch[2], Glenn Jones[4], Michael T. Lam[2], Joseph Lazio[5], Maura McLaughlin[1], Nipuni Palliyaguru[1], Dan Stinebring[6]
1. West Virginia University, Morgantown, WV, United States. 2. Cornell University, Ithaca, NY, United States. 3. National Radio Astronomy Observatory, Charlottesville, VA, United States. 4. Columbia University, New York, NY, United States. 5. Jet Propulsion Laboratory, Pasadena, CA, United States. 6. Oberlin College, Oberlin, OH, United States.

Density fluctuations in the interstellar medium affect pulsar signals by scattering the pulses on their way to Earth, which causes a delay of the pulses' time of arrival at the telescope. The North American Nanohertz Observatory for Gravitational Waves (NANOGrav) uses an array of millisecond pulsars in an effort to directly detect gravitational waves. For this purpose, high precision timing of the pulsars is essential and ultimately a precision of the order of ~100 ns is required. We determine scintillation properties for the millisecond pulsars in the NANOGrav pulsar timing array by creating dynamic spectra of wide L-band timing observations, and find scattering delays of the order of 1--100 ns. We then investigate whether correcting for these delays will provide a higher timing precision and increase our sensitivity to gravitational waves. In addition, we analyse the long term variations of the scattering delays for several pulsars at the 20--30 day cadence of the NANOGrav timing data and find preliminary indications for variations of a factor of ~5. Finally, we discuss the implications of these results for models of the interstellar medium.

114.03 – Detecting correlated gravitational waves with pulsar timing

Rutger Van Haasteren[1]
1. Jet Propulsion Laboratory, Pasadena, CA, United States.

Astrophysical gravitational waves in the nHz regime could become observable within a decade by projects utilising high-precision long term timing of millisecond pulsars. These projects, called pulsar timing arrays, make use of the unique correlated signature gravitational waves induce in the arrival times of pulses from different pulsars. In this quest for correlated signals in pulsar timing delays, one needs to make sure to correctly mitigate correlated noise. I will discuss how our ability to detect gravitational waves is affect by various processes, like imprecisions in the solar system ephemeris and inaccurate terrestrial time standards.

114.04 – A Day in the Life of Millisecond Pulsar J1713+0747: Limits on Timing Precision Over 24 Hours and Implications for Gravitational Wave Detection

Timothy Dolch[1], Matthew Bailes[13], Cees Bassa[9, 15], Ramesh Bhat[13], Bhaswati Bhattacharyya[14], David Champion[10], Shami Chatterjee[1], Ismael Cognard[11], James M. Cordes[1], Kathryn Crowter[8], Paul Demorest[5], Lee S. Finn[7], Emmanuel Fonseca[8], Jason Hessels[15], George Hobbs[12], Gemma

Janssen[9, 15], Glenn Jones[6], Chris Jordan[9], Ramesh Karuppusamy[10], Michael Keith[12], Michael Kramer[10], Alex Kraus[10], Michael T. Lam[1], Patrick Lazarus[10], Joseph Lazio[18], Kejia Lee[10], Lina Levin[4], Kuo Liu[11], Duncan Lorimer[4], Richard N. Manchester[12], Maura McLaughlin[4], Nipuni Palliyaguru[4], Delphine Perrodin[16], Emily Petroff[13], Kaustubh Rajwade[4], Joanna M. Rankin[2], Scott M. Ransom[5], Jason Rosenblum[3], Jayanta Roy[14], Ryan Shannon[12], Benjamin Stappers[9], Dan Stinebring[3], Kevin Stovall[19], Mateus Teixeira[2], Joeri van Leeuwen[15], Willem van Straten[13], Joris Verbiest[17, 10], Weiwei Zhu[8]

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A 24-hour global observation of millisecond radio pulsar J1713+0747 was undertaken by the International Pulsar Timing Array (IPTA) collaboration as an effort to better quantify sources of noise in this object, which is regularly timed for the purpose of detecting gravitational waves (GWs). Given an 8-year timing RMS of 30ns, it is regarded as one of the best precision clocks in the PTA. However, sources of timing noise visible on timescales longer than the usual 20-30min biweekly observation may nonetheless be present. Data from the campaign were taken contiguously with the Parkes, Arecibo, Green Bank, GMRT, LOFAR, Effelsberg, WSRT, Lovell, and Nancay radio telescopes. The combined pulse times-of-arrival provide an estimate of the absolute noise floor, in other words, what unaccounted sources of timing noise impede an otherwise simple sqrt(N) improvement in timing precision, where N is the number of pulses in a single observing session. We present first results of specific phenomena probed on the unusual timescale of tens of hours, in particular interstellar scattering (ISS), and discuss the degree to which ISS affects precision timing. Finally, we examine single pulse information during selected portions of the observation and determine the degree to which the pulse jitter of J1713+0747 varies throughout the course of the day-long dataset.

114.05 – Variable nebula of PSR B1259-63 resolved by Chandra

Oleg Kargaltsev[1], George G. Pavlov[2], Martin Durant[3], Igor Volkov[1], Jeremy Hare[1]
1. George Washington University, Washington, DC, United States. 2. Pennsylvania State University, University Park, PA, United States. 3. University of Toronto, Toronto, ON, Canada.

High-resolution observations of PSR B1259-63/LS 2883 with the Chandra X-ray Observatory resolved the variable extended X-ray emission and revealed the morphology and dynamics of of the outflow. We present the image, variability and spectral analysis results. The extended emission can be interpreted as synchrotron radiation from the pulsar wind thus making LS 2883 the first gamma-ray binary with a pulsar-wind nebula resolved in X-rays. The morphology and the observed apparent motion of the extended X-ray feature suggest that it most likely represents a variable shock produced in the pulsar wind launched near apastron. The research was partially supported by NASA/SAO grant GO-13085.

114.06 – High-energy gamma-rays from pulsar wind nebula 3C 58

John W. Hewitt[1, 2]
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Contributing teams: Fermi-LAT Collaboration

Energetic young pulsars provide excellent laboratories in which to study the acceleration and diffusion of relativistic particles. Here we report on the detection of gamma-ray emission from 3C58, the nebula of PSR J0205+6449, and possibly associated with supernova SN 1181. Using 4 years of Fermi-LAT data, the nebula is clearly identified as a hard power-law source in the off-pulse of PSR J0205+6449 and above 10 GeV. In combination with previous TeV upper limits, we explore the origins for high energy gamma-ray emission from the PWN. The LAT detection places an important constraint on emission

models of the nebula, helping to constrain the age, energetics and magnetization of the system.

114.07 – TeV-detected young pulsar wind nebulae

Analia Cillis[1], Diego F. Torres[2], Jonatan Martin[2], Emma de Oña[2]
1. Instituto de Astronomía y Física del Espacio, Buenos Aires, Argentina. 2. Institut de Ciencies de l'Espain (IEEC-CSIC), Barcelona, Spain.

More than 20 young pulsar wind nebulae (PWNe) have been detected at very high energies (VHE) by the current Imaging Atmospheric Cherenkov Telescopes (IACT). Such sources constitute the largest population of Galactic sources in this energy range. They are associated to very energetic, young pulsars and usually show an extended emission up to a few tens of parsecs. In this work we present spectral characterization for the young PWNe detected at VHE, using a time-dependent model, spanning over 20 decades in frequency. The PWNe that have been studied in this work are: Crab Nebula, G54.1+0.3, G0.9 +0.1, G21.5-0.9, MSH 15-52, G292.2-0.5, Kes 75 , HESS J1356-645 , CTA 1, HESS J1813-178 . Other young PWNe that have been detected at VHE have not been incorporated due to controversies in the association between the PWN and pulsar or lack of observational data at radio and X-ray frequencies. Some of the most robust findings, which are not affected by the uncertainties of the model, is that all detected PWNe in TeV are particle dominated with magnetic fractions that do not exceed a few percent. None of the PWNe detected at high energies and youth is in equipartition. With respect to the spectrum of particle injection, our result suggest that the process of acceleration in the termination shock wave from the pulsar wind, cooling, advection and diffusion of the accelerated particles is common in young PWNe.

114.08 – Near Infrared Activity Close to the Crab Pulsar Correlated with Giant Gamma-ray Flares

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We describe activity observed in the near-infrared correlated with a giant gamma-ray flare in the Crab Pulsar. The Crab Pulsar has been observed by the Fermi and AGILE satellites to flare for a period of 3 to 7 days, once every 1-1.5 years, increasing in brightness by a factor of 3-10 between 100MeV and 1GeV. We used Keck NIRC2 laser guide star adaptive optics imaging to observe the Crab Pulsar and environs before and during the March 2013 flare. We discuss the evidence for the knot as the location of the flares, and the theoretical implications of these observations. Ongoing target-of-opportunity programs hope to confirm this correlation for future flares.

114.09 – Modelling the gamma-ray flares of the Crab Nebula

Marco Tavani[1, 2]
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The detection of major gamma-ray flaring episodes above 100 MeV from the Crab Nebula is challenging theoretical models of particle acceleration. We will review the recent AGILE and Fermi-LAT data showing both short (hour/day) timescale flares and more prolonged enhanced emission lasting weeks. Gamma-ray emission peaking near 500 MeV is apparently violating standard constraints derived from relativistic cyclotron-limited acceleration and synchrotron cooling. The Crab "flaring phenomenon" shows evidence of "super-acceleration" characterized by: (1) an apparent violation of standard synchrotron cooling and of the MHD approximation, and (2) a radiation-reaction-limited spectrum of accelerated particles producing a quasi mono-energetic distribution. We will discuss several scenarios for super-acceleration including collisionless magnetic field reconnection in specific sites of the Crab Nebula. We will present recent theoretical modelling of the South-East jet in the Nebula, and will address the issue of instabilities and particle acceleration in the jet and in the inner Nebula. Understanding the Crab "flaring phenomenon" will have an important impact for a variety of high-energy astrophysical sources including relativistic jets in Galactic and extragalactic sources.

115 – QSOs, AGN
Oral Session – National Harbor 11 – 06 Jan 2014 10:00 am to 11:30 am

115.01 – Hosts of High-Redshift Quasars and Their Clustering Properties

Xinghai Zhao[1], Yuexing Li[1], Sarah Shandera[1], Donghui Jeong[2]
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With the rapid progress in the large-scale surveys, we now have access to large samples of high-redshift quasars from observations to study their clustering properties. Numerical simulations play an essential role to correctly interpret current and future quasar clustering data. We use high-resolution cosmological hydrodynamical simulations to investigate the formation and the evolution of the high redshift quasars. We study the properties of the host galaxies of these quasars and the luminosity selected black hole mass function, Eddington ratio distribution and the quasar luminosity function. We find good agreements between the predictions from our simulations and the data from the observations. We then study the clustering properties of the selected quasar hosts in the simulations and compare them with the data from the large-scale surveys. We discuss the implications of our results on the future large-scale surveys and possible applications of such data on constraining different cosmological models.

115.02 – Luminous Radio-Quiet Red Quasars at <i>z</i> ? 2.5: Feedback and Massive Black Hole Assembly

Eilat Glikman[1, 5], Tanya Urrutia[2], Mark Lacy[3], Stanislav G. Djorgovski[4], Matthew Graham[4], C. M. Urry[5]
1. Middlebury College, Middlebury, VT, United States. 2. Leibniz Institut fur Astrophysik , Potsdam, Germany. 3. NRAO, Charlottesville, VA, United States. 4. California Institute of Technology, Pasadena, CA, United States. 5. Yale University, New Haven, CT, United States.

We present early results from a survey to find radio quiet reddened quasars. We select the reddest objects in a cross match between WISE, 2MASS and SDSS over 2000 deg^2 along an equatorial stripe in the North Galactic Cap. These sources are the radio quiet analogs to the FIRST-2MASS quasars, which we have studied in great detail and find that they are predominantly driven by major mergers, and exhibit strong evidence for feedback in the form of winds seen in broad absorption lines. Near-infrared and optical spectroscopy of this WISE-selected sample reveals that their rest frame UV emission lines are narrow, appearing as Type II spectra, but their Balmer lines, seen in the near-infrared, are extremely broad and strong. As with the FIRST-2MASS radio-selected sample, they also show evidence for feedback in the form of winds. We see broad absorption lines as well as blue-shifted, double-peaked narrow lines in some cases, suggestive of either strong winds or dual AGN.

115.03 – Physical Properties of Luminous Dust Poor Quasars

Hyunsung David Jun[1], Myungshin Im[1]
1. Seoul National University, Seoul, Seoul, Korea, Republic of.

We identify and characterize a population of luminous dust poor quasars at $z<5$, showing little IR emission from the dusty structure of active galactic nuclei (AGNs). This class of AGNs discovered at $z>6$, is yet poorly understood in terms of number evolution or of any dependence on physical properties. In order to better understand the observational features of luminous dust poor quasars, we searched for large area survey databases to compile a rest-frame UV to IR library of 41,000 optically selected type-1 quasars. After fitting the broad-band spectral energy distributions with accretion disk and dust model components, we find 0.6\% of our sample to be hot dust poor under the NIR-to-optical flux ratio selection compatible with Jiang et al. (2010). The blue UV-optical continuum slope of dust poor quasars, together with the NIR-MIR luminosity correlations are presented. Next, we provide the number evolution of the dust poor fraction with redshift, for given bolometric luminosity. Also, we find the low BH mass and high Eddington ratio, to be connected with the dust poorness of AGNs. Finally, we provide models that explain the occurrence and physical properties of dust poor quasars, which is best explained as in a rapidly growing evolutionary state.

115.04 – The Host Galaxies of High-Luminosity Obscured Quasars at z~2.5

Nicholas Ross[1, 2], Michael A. Strauss[3], Jenny E. Greene[3], Nadia L. Zakamska[4], W. N. Brandt[5], Rachael Alexandroff[4], Guilin Liu[4], Paul S. Smith[6]
1. Drexel University, Philadelphia, PA, United States. 2. Lawrence Berkeley National Lab, Berkeley, CA, United States. 3. Princeton University, Princeton, NJ, United States. 4. Johns Hopkins University,

Baltimore, MD, United States. 5. Penn State University, State College, PA, United States. 6. University of Arizona, Tuscon, AZ, United States.
Contributing teams: The SDSS-III BOSS Quasar Working Group

Active Galactic Nuclei play a key role in the evolution of galaxies. However, very little is known about the host galaxies of the most luminous quasars at redshift z~2.5, the epoch when massive black hole growth peaked. The brightness of the quasar itself, which can easily outshine a galaxy by a large factor, makes it very difficult to study emission from extended gas or stars in the host galaxy. However, we have imaged the extended emission from the host galaxies of a unique sample of six optically extinguished (Type II) luminous quasars with z~2.5, with the Hubble Space Telescope (Cycle 20, GO 13014) using ACS/F814W to access the rest-frame near-ultraviolet, and WFC3/F160W for the rest-frame optical longward of 4000A. These objects are selected from the spectroscopic database of the SDSS/Baryon Oscillation Spectroscopic Survey to have strong, narrow emission lines and weak continua. With these images, we have quantified the luminosity, morphology, and dynamical state of the host galaxies, and searched for extended scattered light from the obscured central engine. These observations are the first comprehensive study of both host galaxy light and scattered light in high-luminosity quasars at the epoch of maximum black hole growth, and give insights into the relationship between host galaxies and black holes during this important, and yet largely unexplored period.

115.05 – Galaxy Clustering around Low Redshift Quasars

Alireza Rafiee[1], Jennifer E. Scott[1, 4], Jill Bechtold[2], Erica Ellingson[3]
1. Towson University, Towson, MD, United States. 2. University of Arizon, Tucson, AZ, United States. 3. University of Colorado, Boulder, CO, United States. 4. NASA's Goddard Space Flight Center, Greenbelt, MD, United States.

We present a study of the clustering of galaxies around low redshift quasars. Using data from the 90Prime imager on the Bok 90 inch telescope at Kitt Peak National Observatory, we have created a deep survey (fainter than mag ~23) of wide fields (~70 arcmin) around 14 bright quasars with $0.064 < z < 0.37$ in 4 SDSS filters, u, g, r, and i. Using standard techniques, we calculate the amplitude of the quasar-galaxy clustering in these fields. Also, from the angular correlation of quasars and galaxies in this sample, we derive the correlation length for quasar-galaxy clustering. We discuss the implications for models of quasar-galaxy co-evolution.

115.06 – The Role AGN Play in the Evolution of Quasars Host Galaxies with Spectral Signatures of Post-Starburst Stellar Polulations

Sabrina Cales[1], Michael S. Brotherton[2], Zhaohui Shang[3], Vardha Nicola Bennert[4], Gabriela Canalizo[5], Aleksandar M. Diamond-Stanic[6]
1. Universidad de Concepcion, Concepcion, Bio-Bio, Chile. 2. University of Wyoming, Laramie, WY, United States. 3. Tianjin Normal University, Tianjin, China. 4. Cal Poly San Luis Obispo, San Luis Obispo, CA, United States. 5. University of California, Riverside, Riverside, CA, United States. 6. University of California, San Diego, San Diego, CA, United States.

Motivation: Our understanding of the link between galaxies and the active galactic nuclei (AGN) they host is crucial for our understanding of galaxy evolution, a major question for astronomy today. As such, galaxies that harbor both luminous, broad-lined AGN phenomenon and massive, post-starburst stellar populations (post- starburst quasars, PSQs) provide a natural laboratory for those studying AGN, galaxies and galaxy evolution alike. PSQs are predicted to be transitioning galaxies whereby both the AGN and post-starburst phenomenon exist simultaneously. Thus studying these objects can prove invaluable for understanding connections between nuclear activity and host galaxy evolution. Project: We present the latest work on the study of PSQs and their role in mutual black hole and galaxy evolution. In particular we utilize AGN/host galaxy light decomposition analysis of high quality imaging and spectroscopic data (including IFU) to look at PSQ morphology and AGN and post-starburst fundamental physical properties.

115.07 – Identifying Ionized Gas Outflows in the Narrow-line Region of Type 2 AGNs

Hyun-Jin Bae[1, 3], Jong-Hak Woo[2, 3]
1. Yonsei University, Seoul, Korea, Republic of. 2. Seoul National University, Seoul, Korea, Republic of. 3. Carnegie Observatories, Pasadena, CA, United States.

We investigate gas outflows in the narrow-line region using a large sample of ~23,000 type 2 AGNs selected from the SDSS DR 7. By measuring the velocity offset of the [O III] λ5007 and Hα emission lines with respect to the systemic velocity derived from the stellar continuum fitting, we find that ~19% of type 2 AGNs exhibit a significant (> 30 km/s) line-of-sight velocity offset of [O III] while Hα displays no or little velocity offset, which is consistent with the expectations of the decelerating outflows. AGNs with a large [O III] velocity offset tend to have a high Eddington ratio, suggesting that the

detected gas outflows are linked to black hole activity. The host galaxies' inclination distributed differently depending on whether the AGNs with blue- or redshifted [O III], supporting the scenario of biconical outflow with dust obscuration. Furthermore, we find that ~11% of AGNs shows comparable velocity offsets of [O III] and Hα larger than 30 km/s, indicating a more complex gas kinematics than the decelerating outflows. The faction of type 2 AGNs with a significant (> 30 km/s) [O III] velocity offset is ~30%, which is lower than that of type 1 AGNs, possibly due to the projection effect.

115.08 – The Third Catalog of Active Galactic Nuclei Detected by the Fermi Large Area Telescope

Sara Cutini[1,2], Benoit Lott[4], Dario Gasparrini[1,2], Stefano Ciprini[1,2], Elisabetta Cavazzuti[3]
1. ASI Science Data Center, Roma, Rome, Italy. 2. Osservatorio Astronomico di Roma, Roma, Rome, Italy. 3. Agenzia Spaziale Italiana, Roma, Rome, Italy. 4. Centre d'Etudes Nucleaires de Bordeaux , Bordeaux, Bordeaux, France.
Contributing teams: Fermi-LAT collaboration

The third catalog of active galactic nuclei (AGNs, 3LAC) detected in gamma-rays by the Fermi Large Area Telescope (LAT) in four years of scientific operation is presented. This catalog will be similar to the previously released second LAT AGN catalog (2LAC) which included approximately 1500 gamma-ray sources located at high Galactic latitudes (|b| > 10°) that were detected with a test statistic (TS) greater than 25 and statistically associated with AGNs. Depending on the availability of archival multiwavelegnth data, the blazars are further classified based on their spectral energy distributions (SEDs). The 3LAC contains many new objects and most of the newly detected AGNs (50%) are of unknown type, and lack spectroscopic information of sufficient quality to determine the strength of their emission lines. The full characterization of the newly detected sources will require more broadband data. Various properties, such as gamma-ray fluxes and photon power-law spectral indices, redshifts, gamma-ray luminosities, variability, and archival radio luminosities and their correlations are presented and discussed for the different blazar classes. We will discuss confirmed trends observed in already in 1LAC and 2LAC as well and present some the novelties arising in the 3LAC.

116 – Results from the Pan-STARRS1 Surveys

Special Session – Maryland Ballroom B – 06 Jan 2014 10:00 am to 11:30 am

PS1, the Pan-STARRS1 Telescope is completing its 3.5 year PS1 Science Mission, supported by the PS1 Science Consortium. The PS1 Surveys include: (1) A 3pi Steradian Survey, (2) A Medium Deep survey of 10 PS1 footprints spaced around the sky; (3) A solar system survey optimized for Near Earth Objects, (4) a Stellar Transit Survey; and (5) a Deep Survey of M31. The PS1 3pi Survey will have covered the sky north of dec=-30 with 12 visits in five bands: g,r,i,z and y or over 60 epochs per point on the sky. This session will focus on the science results to date from the PS1 Science Mission, including discoveries of NEO's, KBO's, brown dwarfs, mapping the dust in the Milky Way, the structure of the Milky Way, galaxies in the local group, ultra luminous supernovae, cosmological supernova, high redshift quasars, galaxy counts and clusters, and Baryon Acoustic Oscillations. We will also present details about the public data release of all PS1 data products through the STScI MAST PS1 Archive. The PS1 Science Consortium consists of The Institute for Astronomy at the University of Hawai'i in Manoa, the Max Planck Institute for Astronomy, Heidelberg and the Max Planck Institute for Extraterrestrial Physics, Garching, The Johns Hopkins University, the University of Durham, the University of Edinburgh, the Queen's University Belfast, the Harvard-Smithsonian Center for Astrophysics, the Los Cumbres Observatory Global Telescope Network Incorporated, and the National Central University of Taiwan, NASA, NSF, University of Maryland, and the Eotvos University.

116.01 – The Pan-STARRS1 Surveys

Kenneth C. Chambers[1]
1. Univ. of Hawaii, Honolulu, HI, United States.

Pan-STARRS1 is approaching the completion of the PS1 Science Mission. Operations of the PS1 System include the Observatory, Telescope, 1.4 Gigapixel Camera, Image Processing Pipeline , PSPS relational database and reduced science product software servers. The Pan-STARRS1 Surveys include: (1) A 3pi Steradian Survey, (2) A Medium Deep survey of 10 PS1 footprints spaced around the sky; (3) A solar system survey optimized for Near Earth Objects, (4) a Stellar Transit Survey; and (5) a Deep Survey of M31. The PS1 3pi Survey has now covered the sky north of dec=-30 with more than 12 visits in five bands: g,r,i,z and y or over ~60 epochs per 0.25 arcsec resolution element on the sky. The performance of the PS1 system, sky coverage, cadence, and data quality of the Pan-STARRS1 Surveys will be presented as well as progress in reprocessing of the data taken to date and the plans for the public release of all Pan-STARRS1 data products in the spring of 2015. The Pan-STARRS1 Surveys (PS1) have been made possible through contributions of the Institute for Astronomy, the University of Hawaii, the Pan-STARRS Project Office, the Max-Planck Society and its participating institutes, the Max Planck Institute for Astronomy, Heidelberg and the Max Planck Institute for Extraterrestrial Physics, Garching, The Johns Hopkins University, Durham University, the University of Edinburgh, Queen's University Belfast, the Harvard-Smithsonian Center for Astrophysics, the Las Cumbres Observatory Global Telescope Network Incorporated, the National Central University of Taiwan, the Space Telescope Science Institute, the National Aeronautics and Space Administration under Grant No. NNX08AR22G issued through the Planetary Science Division of the NASA Science Mission Directorate, the National Science Foundation under Grant No. AST-1238877, the University of Maryland, and Eotvos Lorand University (ELTE).

116.02 – The Pan-STARRS-1 Outer Solar System Key Project: A Status Report

Matthew J. Holman[1]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.
Contributing teams: The PS1 Outer Solar System Team

The Pan-STARRS-1 (PS1) survey is capable of detecting slow-moving objects in the outer solar system. Among these are Trojans, Centaurs, long-period comets, short-period comets, and trans-neptunian objects brighter than magnitude R~22. We have developed a software pipeline to search for these objects. I will present a status report for this pipeline, as well highlights from the PS1 Outer Solar System Key Project.

116.03 – Probing the atmospheres of brown dwarf with benchmark objects identified in Pan-STARRS1

Niall Deacon[1], Michael C. Liu[2], Eugene A. Magnier[2], Katelyn N. Allers[3], Trent J. Dupuy[4], Brendan P. Bowler[2, 5], Kimberly M. Aller[2], William M. Best[2], Michael C. Kotson[2]
1. Max Planck Institute for Astronomy, Heidelberg, Germany. 2. Institute for Astronomy, University of Hawaii, Honolulu, HI, United States. 3. Bucknell University, Lewisburg, PA, United States. 4. Harvard-Smithsonian CfA, Cambridge, MA, United States. 5. California Institute of Technology, Pasadena, CA, United States.
Contributing teams: Pan-STARRS1 Builders

Brown dwarfs have complex atmospheres which have similar temperatures to directly imaged, young extrasolar planets. However as they lack a long-term stable luminosity source due to their lack of hydrogen burning, there is a degeneracy between mass, age, effective temperature and luminosity. This can be broken by identifying brown dwarfs which are either

companions to main sequence stars of known age or are members of kinematic groups in the solar neighbourhood which have their ages determined from higher mass members. Pan-STARRS1 provides an excellent tool for identifying either of these types of benchmark systems due to its excellent red-opitcal sensitivity and proper motion measurements from its multiple epoch coverage. I will outline the results from our highly successful survey for wide benchmark companions to main sequence stars and how we have used these to test models of substellar atmospheres. I will also present our discovery of a remarkable object which is a likely member of the beta Pic young moving group, planetary mass and possibly the best free-floating analogue to young extrasolar planets yet identified.

116.04 – The Dust to 5 kpc from Pan-STARRS1

Eddie Schlafly[1], Gregory Green[2], Douglas P. Finkbeiner[2], Hans-Walter Rix[1]
1. MPIA, Heidelberg, Baden Wuerttemberg , Germany. 2. Harvard, Cambridge, MA, United States.

We present a map of the dust reddening to 5 kpc derived from Pan-STARRS1 stellar photometry. The wide coverage and high-quality photometry of the PanSTARRS-1 mission enables the map to cover almost the entire sky north of declination -30 degrees. We use PanSTARRS-1 photometry for more than 500 million stars to determine the map. Our technique is designed to study the dust in the plane, where many other techniques are stymied by the presence of multiple dust clouds at different distances along each line of sight. The map agrees closely with the Schlegel, Finkbeiner, and Davis (1998; SFD) far-infrared dust map outside the Galactic plane, and the largest differences between the two maps stem from known limitations of SFD. The use of optical data from Pan-STARRS1 yields reddening uncertainty as low as 20 mmag E(B-V) in 7 arcminute pixels.

116.05 – A 3D Dust Reddening Map from Pan-STARRS1

Gregory Green[1], Eddie Schlafly[2], Douglas P. Finkbeiner[1]
1. Harvard Univ., Cambridge, MA, United States. 2. MPIA, Heidelberg, Baaden-Wuerttemberg, Germany.

We present a 3D map of dust reddening in the Milky Way, derived from PS1 photometry of ~600 million stars. We first determine the full probability density of distance, reddening and stellar type for each well observed star in the survey. In each line of sight, we then model dust reddening as a function of distance, inferring a set of dust profiles which are consistent with the stellar distances and reddenings, as described in detail in Green et al. (2013). Our map is thus probabilistic: it reports the range of possible reddenings at each distance along each direction. Our map agrees well with the Schlegel, Finkbeiner and Davis (1998) map of cumulative dust extinction, and additionally reveals a wealth of 3D dust structure. Our map extends to a heliocentric distance of several kiloparsecs, depending on the dust column in each direction, and probes dust columns up to E(B-V) ~ 4. We expect our 3D dust map to be of use in correcting obsevations of Galactic objects, constraining Galactic structure and kinematics, and in determining distances to objects of known reddening.

116.06 – A Panoramic View of the Monoceros Ring

Colin Slater[1], Eric F. Bell[1], Eddie Schlafly[2], Eric Morganson[3], Nicolas Martin[4, 2], Hans-Walter Rix[2]
1. University of Michigan, Ann Arbor, MI, United States. 2. Max Planck Institute for Astronomy, Heidelberg, Germany. 3. Harvard-Smithsonian Center for Astrophysics, Boston, MA, United States. 4. University of Strasbourg, Strasbourg, France.
Contributing teams: The Pan-STARRS1 Consortium

The study of Galactic structure is a prime case where surveys covering a substantial fraction of the entire sky are of critical importance. In particular, previous surveys like SDSS have detected a ring-like structure in the vicinity of the outer Galactic disk known as the Monoceros ring, but the lack of imaging throughout the disk has limited our understanding of its true size, structure, and origin. With Pan-STARRS1 we are able to present a panoramic view of the Monoceros Ring, demonstrating its extent on both the northern and southern sides of the Galactic plane up to substantial heights of 20-30 degrees in Galactic latitude and covering nearly 130 degrees in Galactic longitude. The feature exhibits complex stream-like structures and sharp edges that are substantially unlike smooth models of the disk. To guide our understanding of the morphology we present a comparison to two N-body simulations, one where tidal debris from an accreted dwarf forms the Monoceros Ring and another where a dwarf disrupts the Galactic disk and produces structures at high latitude. These simulations broadly illustrate the link between possible formation mechanisms and the resulting morphological features, further guiding our understanding of the ring's origin.

116.07 – Pan-STARRS-1 Medium Deep Survey Status

Mark Huber[1]
1. Institute for Astronomy, Univ. of Hawaii, Honolulu, HI, United States.
Contributing teams: PS1SC/IPP Team

The Panoramic Survey Telescope And Rapid Response System-1 (Pan-STARRS-1, PS1) has been in full operation since Spring

2010 and is approaching the conclusion of the PS1 Science Consortium observational program. The Medium Deep Survey (MDS) component of the program is allocated 25% of the time to regularly visit 10 fields (~7 sq. deg. each), many with significant multi-wavelength overlap from previous and concurrent surveys (i.e., SDSS, DEEP2, CDFS, COSMOS, GALEX). The cadence generally covers the g,r,i,z filters every 3 days (the y filter primarily during bright time) with a nightly stack depth of r,i~16--23.5 mag. While regularly supporting the ongoing transient event discovery and science programs, development work is continuing to also improve single exposures and on through to the production of deep stacks for the final data products. http://ps1sc.org/

116.08 – The Pan-STARRS 1 Medium Deep Field Variable Star Catalog

Heather Flewelling[1]
1. University of Hawaii, Honolulu, HI, United States.

The Pan-STARRS 1 (PS1) telescope is a 1.8 meter survey telescope with a 1.4 gigapixel camera located on Haleakala, HI. One of the PS1 surveys, the Medium Deep Survey, has extensive time coverage for 10 7 square degree fields. For each field, 8 exposures per filter per night are taken, usually 2-3 filters per night, resulting in roughly 3000 data points per star with a total time span of 3 years. We analyzed this data to find several hundred periodic variable stars, with periods between a few minutes to a few days, most of which have never been classified as variable before. We present properties and statistics of this set of variable stars.

116.09 – Systematic Uncertainties Associated with the Cosmological Analysis of the First Pan-STARRS1 Type Ia Supernova Sample

Daniel Scolnic[1], Armin Rest[2]
1. Johns Hopkins University, Baltimore, MD, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: PS1 Transients Group

We probe the systematic uncertainties from the 117 Type Ia supernovae (SN Ia) in the Pan-STARRS1 (PS1) sample along with 201 SN Ia from combined low-redshift surveys. We find that the current largest systematic uncertainty is from the calibration of the PS1 and low-z photometric systems followed by incomplete understanding of the intrinsic color of SN Ia. In an effort to improve the absolute photometric calibration of the PS1 sample, we increase the sample of observed Calspec standards from 7 to 12 to define the PS1 calibration system. The PS1 and SDSS-II calibration systems are compared and discrepancies up to ? 0.02 mag are found. We verify with the PS1 sample the recently discovered asymmetry of the color-luminosity relation. We find that uncertainties related to the underlying SNIa color model may be up to 5% in w. We include the first estimates of masses of host galaxies of PS1 supernovae and find only a small difference in distance residuals for galaxies with high and low masses. Evidence for a non-linear light curve width-luminosity relation is seen that may explain observed trends between SN Ia distances and widths of their light curves. We present our derived results for the equation of state of dark energy and the matter density of the universe. We also discuss how these results depend on whether we use external constraints from measurements of the CMB by Planck or WMAP.

116.10 – SN IA in the IR: RAISIN A progress report

Robert P. Kirshner[1]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.
Contributing teams: The RAISIN TEAM

SN Ia have proven to be a powerful tool for cosmology. Near-IR observations of SN Ia promise even better results because the supernovae are more nearly standard candles at those wavelengths and absorption by dust is diminished by a factor of 4 compared to rest-frame B-band observations. Near IR observations of cosmologically-distant SN Ia discovered with PanSTARRS are underway using the infrared camera on the Hubble Space Telescope (GO-13046). These targets are discovered in the difference images created in the CfA/JHU pipeline, confirmed spectroscopically at the MMT, Magellan, Gemini, or Keck, and inserted in a non-disruptive way into the HST observing schedule for WFC3-IR. We have observed over 20 SN Ia in the range 0.2 < z < 0.5 during Cycle 21 and this is a progress report on the analysis. The final results require a repeat observation after the supernova has faded. Those will be completed in 2014, but we have a sufficient sample of objects for which the supernova is well separated from the host galaxy to illustrate the power of this technique. Preliminary analysis shows HST data can reduce the uncertainty in the distance to each supernova by a factor or 2. Sufficiently large supernova samples have been gathered at all redshifts so that statistical errors in interesting parameters (like the dark energy equation-of-state index (1 +w)), have been driven down to the same level as the systematic errors (about 7%). Further progress is limited by our ability to master the systematic errors. These include the correction for luminosity based on the light curve shape and the correction based on intrinsic color and reddening by dust. Since SN IA behave better in the IR in both these ways, there is reason to expect that this approach will be effective in driving down the systematic errors over time. If we are diligent in building up the size of the sample that is observed in the rest-frame infrared, we can expect more certain knowledge of the properties of dark energy. Unsolved problems include constructing precise K-corrections and firming up the

fundamental photometric system in y, J, H, and K, but this approach seems a promising one for the HST era now, JWST soon, and WFIRST in good time.

116.11 – Early science from the Pan-STARRS1 Optical Galaxy Survey (POGS): Maps of stellar mass and star formation rate surface density obtained from distributed-computing pixel-SED fitting

David A. Thilker[1], Kevin Vinsen[2]
1. Johns Hopkins Univ., Baltimore, MD, United States. 2. International Centre for Radio Astronomy Research (ICRAR), Perth, WA, Australia.
Contributing teams: PS1 Galaxy Properties Key Project

To measure resolved galactic physical properties unbiased by the mask of recent star formation and dust features, we are conducting a citizen-scientist enabled nearby galaxy survey based on the unprecedented optical (g,r,i,z,y) imaging from Pan-STARRS1 (PS1). The PS1 Optical Galaxy Survey (POGS) covers 3? steradians (75% of the sky), about twice the footprint of SDSS. Whenever possible we also incorporate ancillary multi-wavelength image data from the ultraviolet (GALEX) and infrared (WISE, Spitzer) spectral regimes. For each cataloged nearby galaxy with a reliable redshift estimate of z < 0.05 - 0.1 (dependent on donated CPU power), publicly-distributed computing is being harnessed to enable pixel-by-pixel spectral energy distribution (SED) fitting, which in turn provides maps of key physical parameters such as the local stellar mass surface density, crude star formation history, and dust attenuation. With pixel SED fitting output we will then constrain parametric models of galaxy structure in a more meaningful way than ordinarily achieved. In particular, we will fit multi-component (e.g. bulge, bar, disk) galaxy models directly to the distribution of stellar mass rather than surface brightness in a single band, which is often locally biased. We will also compute non-parametric measures of morphology such as concentration, asymmetry using the POGS stellar mass and SFR surface density images. We anticipate studying how galactic substructures evolve by comparing our results with simulations and against more distant imaging surveys, some of which which will also be processed in the POGS pipeline. The reliance of our survey on citizen-scientist volunteers provides a world-wide opportunity for education. We developed an interactive interface which highlights the science being produced by each volunteer's own CPU cycles. The POGS project has already proven popular amongst the public, attracting about 5000 volunteers with nearly 12,000 participating computers, and is growing rapidly.

116.12 – Discovery of high-redshift quasars from Pan-STARRS1.

Eduardo Banados[1], Bram Venemans[1], Eric Morganson[2], Roberto Decarli[1], Fabian Walter[1], Kenneth C. Chambers[3], Hans-Walter Rix[1], Emanuele Farina[1], Gisella De Rosa[4]
1. Max Planck Institute for Astronomy, Heidelberg, Germany. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. Institute for Astronomy, University of Hawaii, Manoa, HI, United States. 4. Department of Astronomy, The Ohio State University, Columbus, OH, United States.
Contributing teams: Pan-STARRS

High-z quasars provide unique information about the evolution of supermassive black holes (SMBHs) and the intergalactic medium (IGM) at early cosmic times. Over the last decade, numerous studies have established a sample of ~60 quasars at 5.5<z<6.5, mostly discovered in optical surveys (e.g. SDSS and CFHQS). These studies have established the existence of SMBHs less than a Gyr after the Big Bang, and the presence of almost complete Gunn-Peterson absorption, indicating the end of the reionization at z~6. These findings strongly suggest that fundamental changes are happening in the IGM at z~6-7. The discovery and characterization of a statistically significant sample of bright quasars in this redshift range is crucial to further study this important era in the history of the Universe. The Pan-STARRS1 (PS1) 3pi survey represents a fundamental step forward in high-z quasar searches for three reasons: 1) it covers more than two times the area observed with SDSS; 2) it goes significantly deeper than SDSS in the reddest bands where z~6 quasars are visible; and 3) the additional y-band enables the search for luminous quasars beyond the SDSS limit, z>6.5. In early 2013, PS1 produced its first 3pi stacked catalog, marking a leap forward in terms of depth and area. Already in 2012 we discovered the first PS1 high-z quasar (Morganson et al 2012). Our aim is to discover a complete sample of 5.7<z<6.4 quasars in the 3pi PS1 area, sensitive to a magnitude of z=21.4, i.e. nearly a magnitude deeper than the SDSS quasar search. During 2013, we have so far discovered 8 additional z~6 quasars (Bañados et al 2013). The new sample shows a variety of quasars properties, in terms of both luminosities and spectral features. The fraction of weak-line emission quasars found in this work is much higher than in previous studies, implying that the z~6 quasar population might be more diverse than previously thought.

116.13 – A Pan-STARRS-1 Astrometric and Photometric Search for Substellar Young Moving Group Members

Kimberly M. Aller[1], Michael C. Liu[1], Eugene A. Magnier[1]
1. University of Hawaii, Manoa, Honolulu, HI, United States.

Young (~10-100 Myr) moving groups (YMGs) are coeval, comoving groups of stars which have migrated from their birthsites after formation. They provide a valuable evolutionary link between ongoing star formation in molecular clouds (~1 Myr) and old field stars (?1 Gyr). Previous searches for YMGs, based on optical surveys such as *Hipparcos* and the Palomar Sky Survey were insensitive to the lowest mass members (~0.5 M_{sun}), meaning that ~75% of the YMG census remained unknown. Recent surveys using enhanced UV emission (i.e. from GALEX) have begun to add to the census of higher mass members, revealing these low-mass stellar members. However, the cool, substellar members have remained elusive as only 5 are known. We have combined optical photometry and proper motions from Pan-STARRS-1 (PS1) to increase the search volume for these missing substellar members by a factor of ~50-100. PS1 is unique because its large area coverage encompasses the sparsely-distributed YMGs and its far-red sensitivity (z & y bands) allows detection of substellar members out to ~100 pc. In addition, PS1 provides high quality astrometry with several epochs spanning 3 yrs, allowing us to determine precise proper motions, essential for distinguishing candidate YMG members from old field stars, with uncertainties of 15 mas/yr for faint objects (z~18.5 mag). We have identified candidate young brown dwarf members and spectroscopically confirmed the youth of several candidates with NIR spectra. These young brown dwarf members can be used to determine the substellar IMF in YMGs and are essential benchmarks for defining the spectral evolution of brown dwarfs with age.

116.14 – A Pan-STARRS1-based recalibration of the Sloan Digital Sky Survey photometry

Douglas P. Finkbeiner[1], Eddie Schlafly[2], Gregory Green[1]
1. Harvard Univ., Cambridge, MA, United States. 2. MPIA, Heidelberg, Germany.

We present a recalibration of the SDSS DR9 photometry with new flat fields and zero points derived from Pan-STARRS. Using PSF photometry of 60 million stars with 16 < r < 20, we obtain SDSS flat-field and amplifier gain corrections stable to 3 millimagnitudes (mmag) in g,r,i,z bands and 15 mmag in u band. We also identify transient non-photometric periods in SDSS ("contrails") based on photometric deviations co-temporal in SDSS bands. The recalibrated SDSS and PS1 photometry agree with systematics at the 7 mmag level.

116.15 – Early Results and Plans for the Time Domain Spectroscopic Survey

Paul J. Green[1], Scott F. Anderson[2], Eric Morganson[1], John J. Ruan[2]
1. Harvard-Smithsonian CfA, Cambridge, MA, United States. 2. University of Washington, Seattle, WA, United States.
Contributing teams: PS1, SDSS-III, SDSS-IV

With PanSTARRS-1 just finishing and LSST over the horizon, time-domain astronomy is a celestial tsunami just now hitting our shores. We outline the Time Domain Spectroscopic Survey (TDSS) - the first large-scale, all-sky spectroscopic survey of celestial variables. As part of SDSS-IV eBOSS program, the TDSS has begun obtaining BOSS-quality spectroscopy of variable objects selected primarily from the PS1 3pi survey. During the duration of SDSS-IV (2014-2020), TDSS should garner of order 1E+05 first-ever spectra of variables to i-band mag about 21. While AGN will dominate the sample, all kinds of variable stars will also be revealed, including RR Lyr, flare stars, eclipsing binaries, pulsating white dwarfs and more. We will outline target selection, and discuss early results. We also describe a TDSS subprogram testing for spectroscopic variability by obtaining 2d or 3d epoch spectra of several carefully chosen source classes.

117 – Star Formation I

Oral Session – Potomac Ballroom C – 06 Jan 2014 10:00 am to 11:30 am

117.01 – Structure of massive star forming clumps from the Red MSX Source Survey

Charles C. Figura[1], James S. Urquhart[2], Lawrence Morgan[3]
1. Wartburg College, Waverly, IA, United States. 2. Max Planck Institute for Radio Astronomy, Bonn, Germany. 3. University of Hertfordshire, Hatfield, United Kingdom.

We present ammonia (1,1) and (2,2) emission maps of 61 high-mass star forming regions drawn from the Red MSX Source (RMS) Survey and observed with the Green Bank Telescope's K-Band Focal Plane Array. We use these observations to investigate the spatial distribution of the environmental conditions associated with this sample of embedded massive young stellar objects (MYSOs). Ammonia is an excellent high-density tracer of star-forming regions as its hyperfine structure allows relatively simple characterisation of the molecular environment. These maps are used to measure the column density, kinetic gas temperature distributions and velocity structure across these regions. We compare the distribution of these properties to that of the associated dust and mid-infrared emission traced by the ATLASGAL 870 micron emission maps and the *Spitzer* GLIMPSE IRAC images. We present a summary of these results and highlight some of more interesting finds.

117.02 – [CII] 158 μm Emission as a Star Formation Tracer

Rodrigo Herrera-Camus[1], Alberto D. Bolatto[1], Mark G. Wolfire[1], Daniela Calzetti[2]
1. University of Maryland, College Park, MD, United States. 2. University of Massachusetts, Amherst , MA, United States.
Contributing teams: KINGFISH Team

The [CII] 158 μm transition is a major coolant for the interstellar gas and has great potential as a star formation rate tracer. Thanks to ALMA, the [CII] 158 μm line will be detected in normal, star forming galaxies at redshift z>1. Using a sample of 49 nearby galaxies observed by Herschel as part of the KINGFISH project, we analyze how reliable is to measure the star formation rate using the [CII] 158 μm transition. We present resolved correlations of the [CII] 158 μm transition with recently published prescriptions for star formation rates based on 24 μm, Hα and FUV emission. We find a strong, nearly linear correlation between the [CII] 158 μm luminosity surface density and the star formation rate surface density. We conclude that the [CII] emission can be used for measurements of SFRs in normal, star forming galaxies in the absence of strong AGNs. The uncertainty associated to the [CII]-SFR calibration is ~0.2 dex. We test the correlation using a simple model based on the Starburst99 code to connect the star formation rate of a stellar population to the [CII] 158 μm emission. We find that most of the regions can be described by a star formation episode that is 20-100 Myr old and photoelectric heating efficiencies in the 1-3%. range The variations in the latter appear to drive much of the scatter in the [CII]-SFR correlation.

117.03 – Star Formation Rate and Gas Relations in the Arp 299 Merger from the VIXENS Survey

Amanda L. Heiderman[1, 2], Neal J. Evans [3], Karl Gebhardt[3], Guillermo A. Blanc[4], Timothy Davis[5], Casey J. Papovich[6], Remco van den Bosch[7], Daisuke Iono[8], Min Su Yun[9]
1. University of Virginia, Charlottesville, VA, United States. 2. NRAO, Charlottesville, VA, United States. 3. University of Texas at Austin, Austin, TX, United States. 4. Observatories of the Carnegie Institution, Pasadena, CA, United States. 5. ESO, Garching, Germany. 6. Texas A&M University, College Station, TX, United States. 7. MPIA, Heidelberg, Germany. 8. Nobeyama Radio Observatory, Minamisaku, Nagano, Japan. 9. University of Massachusetts, Amherst, MA, United States.
Contributing teams: VIXENS team

We investigate the relationship between star formation and gas content in late interaction phase merger Arp 299 from the VIRUS-P Investigation of the eXtreme ENvironments of Starbursts (VIXENS) integral field unit survey. By comparing H-alpha, Pa-alpha and 24um data to CO(1-0), CO(2-1), HCN(1-0), HCO+(1-0), and HI maps, we explore the relation between the star formation rate and gas surface densities on spatially resolved ~kpc scales. We find discrepancies from known extragalactic spatially resolved relations in nearby spiral galaxies and disk-averaged relations in high-z mergers.

117.04 – Relationship Between Dense Gas and Total Infrared Luminosity Along Spiral Arms in M51

Melissa N. Louie[1], Jin Koda[1], Fumi Egusa[2]
1. Stony Brook University, Stony Brook, NY, United States. 2. JAXA, Sagamihara, Kanagawa, Japan.

We investigate the relationship between the dense molecular gas tracer, HCN (J=1-0), luminosity and total infrared luminosity in nearby grand design spiral, M51. Previous work has shown a near linear correlation between the total infrared luminosity and HCN luminosity between Galactic dense cores and spirals and starburst galaxies. This relationship spans over seven orders of magnitude. Our aim is to test this relationship using intermediate points with HCN luminosities larger than galactic dense cores and smaller than that of total spiral and starburst galaxies. The linear correlation between HCN and total infrared luminosity continues to hold for gas along spiral arms in M51, suggesting that HCN is tracing the gas most relevant for star formation. The HCN emission was mapped using interferometric observations from the Owens Valley Radio Observatory and Combined Array for Research in Millimeter Astronomy. We compare the total recovered HCN emission to single dish maps taken with the Green Bank Telescope. Total infrared maps are made from Spitzer MIPS 24 micron and Hershel PACS 70micron and 160 micron maps.

117.05 – Bridging the Galactic-Extragalactic divide with WISE: a Galactic perspective on star-formation-rate to gas density relations in massive star forming regions

Xavier Koenig[1] , David Leisawitz[2]
1. Yale University, New Haven, CT, United States. 2. NASA Goddard Space Flight Center, Greenbelt, MD, United States.

We present initial results from a survey of Galactic massive star forming regions to investigate the origins of the observed relation between star formation rate and gas surface densities seen in studies of external galaxies. We use an adaptation of the star counts method of the Cores to Disks survey (Evans et al. 2009) to derive full-cloud star formation rates using WISE and 2MASS infrared data for a set of Galactic massive star forming regions and CO and HI data to compute cloud gas masses. We specifically select regions massive enough to be analogous to those seen in studies of resolved external galaxies (e.g. Calzetti et al. 2005). The regions are more massive than those in the Cores to Disks survey, and we survey entire molecular clouds in contrast to the very localized studies of Wu et al. (2010). Our results provide further support to show that the empirical Kennicutt-Schmidt relation between gas and star-formation rate surface densities arises from the properties of unresolved measurements of giant molecular clouds. Our survey is part of an ongoing effort to utilize the all-sky coverage of WISE and 2MASS to understand global scaling relations in star forming galaxies.

117.06 – Point Sources in Herschel's HERITAGE Key Project: Star Formation in the Magellanic Clouds

Jonathan P. Seale[1] , Margaret Meixner[1]
1. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: HERITAGE

The HERschel Inventory of The Agents of Galaxy Evolution (HERITAGE) is a Herschel Key Project that used 237.7 hours of time to obtain SPIRE/PACS parallel imaging (100, 160, 250, 350, and 500 microns) of the Large Magellanic Cloud, Small Magellanic Cloud, and Magellanic Bridge. A follow-up to the Spitzer program SAGE, the HERITAGE images provide key insights into the life cycle of galaxies because the far-infrared and submm emission from dust grains is an effective tracer of the coldest ISM dust, the most deeply embedded young stellar objects, and the dust ejected over the lifetime of massive stars. Several thousand far-IR point sources were identified in each galaxy, including planetary nebulae, supernova remnants, extreme/post-AGB stars, and background galaxies, but most of which are young forming stars enshrouded in dust. We present the new HERITAGE point-source catalog, a band-merged HERITAGE catalog combining near- to far-IR observations, and source catalogs containing several thousand YSOs (most newly-identified) in the Magellanic Clouds.

117.07D – Massive Star Formation Viewed through Extragalactic-Tinted Glasses

Sarah Willis[1,2], Massimo Marengo[1], Howard A. Smith[2], Lori Allen[3]
1. Iowa State University, Ames, IA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. National Optical Astronomy Observatory, Tucson, AZ, United States.

Massive Galactic star forming regions are the local analogs to the luminous star forming regions that dominate the emission from star forming galaxies. Their proximity to us enables the characterization of the full range of stellar masses that form in these more massive environments, improving our understanding of star formation tracers used in extragalactic studies. We have surveyed a sample of massive star forming regions with a range of morphologies and luminosities to probe the star formation activity in a variety of environments. We have used Spitzer IRAC and deep ground based J, H, Ks observations to characterize the Young Stellar Object (YSO) content of 6 massive star forming regions. These YSOs provide insight into the rate and efficiency of star formation within these regions, and enable comparison with nearby, low mass star forming regions as well as extreme cases of Galactic star formation including 'mini-starburst' regions. In addition, we have conducted an in-depth analysis of NGC 6334 to investigate how the star formation activity varies within an individual star forming region, using Herschel data in the far-infrared to probe the earliest stages of the ongoing star formation activity.

118 – The Sun
Oral Session – Maryland Ballroom C – 06 Jan 2014 10:00 am to 11:30 am

118.01 – Solar Activity and Motions in the Solar Chromosphere and Corona at the 2012 and 2013 Total and Annular Eclipses in the U.S., Australia, and Africa

Jay M. Pasachoff[1], Bryce A. Babcock[1], Allen B. Davis[1], Marek Demianski[1], Robert Lucas[1], Muzhou Lu[1,2], Ronald Dantowitz[3], Vojtech Rusin[4], Metod Saniga[4], Daniel B. Seaton[5], Pavlos Gaintatzis[6], Aristeidis Voulgaris[6], John H. Seiradakis[6], Dale E. Gary[7], Shaheda B. Shaik[7]
1. Williams College, Williamstown, MA, United States. 2. Barrie School, Silver Spring, MD, United States. 3. Dexter Southfield School, Brookline, MA, United States. 4. Astronomical Institute, Tatranska Lomnica, Slovakia. 5. Royal Obs. Belgium, Brussels, Belgium. 6. Aristotle U. Thessaloniki, Thessaloniki, Greece. 7. NJIT, Newark, NJ, United States.

Our studies of the solar chromosphere and corona at the 2012 and 2013 eclipses shortly after cycle maximum 24 (2011/2012) of solar activity (see: http://www.swpc.noaa.gov/SolarCycle/) involved radio observations of the 2012 annular eclipse with the Jansky Very Large Array, optical observations of the 2012 total eclipse from Australia, optical observations of the 2013 annular eclipse from Tennant Creek, Australia, and the 3 November 2013 total solar eclipse from Gabon. Our observations are coordinated with those from solar spacecraft: Solar Dynamics Observatory AIA and HMI, Hinode XRT and SOT, SOHO LASCO and EIT, PROBA2 SWAP, and STEREO SECCHI. Our 2012 totality observations include a CME whose motion was observed with a 37-minute interval. We include first results from the expedition to Gabon for the 3 November 2013 eclipse, a summary of eclipse results from along the path of totality across Africa, and a summary of the concomitant spacecraft observations. The Williams College 2012 expeditions were supported in part by NSF grant AGS-1047726 from Solar Terrestrial Research/NSF AGS, and by the Rob Spring Fund and Science Center funds at Williams. The JVLA is supported by the NSF. The Williams College 2013 total-eclipse expedition was supported in part by grant 9327-13 from the Committee for Research and Exploration of the National Geographic Society. ML was also supported in part by a Grant-In-Aid of Research from the National Academy of Sciences, administered by Sigma Xi, The Scientific Research Society (Grant ID: G20120315159311). VR and MS acknowledge support for 2012 from projects VEGA 2/0003/13 and NGS-3139-12 of the National Geographic Society. We are grateful to K. Shiota (Japan) for kindly providing us with some of his 2012 eclipse coronal images. We thank Alec Engell (Montana State U) for assistance on site, and Terry Cuttle (Queensland Amateur Astronomers) for help with site arrangements. We thank Aram Friedman (Ansible Technologies), Michael Kentrianakis, and Nicholas Weber (Dexter Southfield School) for collaboration on imaging at the Australian total eclipse.

118.02 – Fermi Large Area Telescope observations of high-energy gamma-ray emission from solar flares

Melissa Pesce-Rollins[1], Nicola Omodei[2], Vahe Petrosian[2]
1. INFN-Pisa, Pisa, Pi, Italy. 2. Stanford University, Stanford, CA, United States.
Contributing teams: Fermi LAT Collaboration

With the current solar cycle reaching its maximum, the Fermi observatory has proven to play an active role in the study of solar flares. The Large Area Telescope (LAT) on-board Fermi has detected >30 MeV gamma-ray emission associated with GOES M-class and X-class X-ray flares accompanied by coronal mass ejections and solar energetic particle events. These detections include both the impulsive and the long duration phases including the ~20 hours of extended emission from the 2012 March 7 X-class flares. Accurate localization with the Fermi LAT of the gamma-ray production site(s) coincide with the solar active region from which X-ray emissions associated with the 2012 March 7 X-class flares originated. In this talk I present an overview of the Fermi solar flare detections over the past five years of operation.

118.03D – STUDYING THE POLARIZATION OF HARD X-RAY SOLAR FLARES WITH THE GAMMA RAY POLARIMETER EXPERIMENT (GRAPE)

Camden Ertley[1]
1. The University of New Hampshire, Durham, NH, United States.

The degree of linear polarization of hard X-rays (50-500 keV) can provide a better understanding of the particle acceleration mechanisms and the emission of radiation during solar flares. Difficulties in measuring the linear polarization has limited the ability of past experiments to place constraints on solar flare models. The Gamma RAy Polarimeter Experiment (GRAPE) is a balloon-borne Compton polarimeter designed to measure polarization in the 50 - 500 keV energy range. This energy range minimizes the thermal contamination that can potentially affect measurements at lower energies. This research focuses on the analysis of data acquired during the first high altitude balloon flight of the GRAPE payload in 2011. During this 26 hour balloon flight two M-class flares were observed. The analysis effort includes the development of a Monte Carlo simulation of the full instrument payload with the GEANT4 toolkit. The simulations were used in understanding the background environment, creating a response matrix for the deconvolution of the energy loss spectra, and determining the modulation

factor for a 100% linearly polarized source. We report on the results from the polarization analysis of the solar flare data. The polarization and spectral data can be used to further our understanding of particle acceleration in the context of current solar flare models.

118.04 – Probing Magnetic Energy Release in a Solar Flare with Radio Dynamic Imaging Spectroscopy

Bin Chen[1,2], Timothy S. Bastian[3], Dale E. Gary[2], Stephen M. White[4]
1. University Corporation for Atmospheric Research, Boulder, CO, United States. 2. New Jersey Institute of Technology, Newark, NJ, United States. 3. National Radio Astronomy Observatory, Charlottesville, VA, United States. 4. Air Force Research Lab, Albuquerque, NM, United States.

Solar flares involve sudden release of magnetic energy that is previously stored in the Sun's corona. Yet details of the flare energy release processes are still poorly understood. Solar radio bursts are intense and short-lived radio emissions that occur in solar flares. They are believed to be intimately related to flare energy release processes. However, their potential in diagnosing flare energy release has been greatly limited by the lack of simultaneous spatial information. The upgraded Karl G. Jansky Very Large Array (VLA) provides the first opportunity of radio synthesis imaging along with high spectral and temporal resolution, making the new technique of radio dynamic imaging spectroscopy possible. We report VLA observations of a solar flare event using this new technique, during which a rich variety of radio bursts are recorded. With the help of concurrent data in extreme ultra-violet and X-ray wavelengths, these observations allow us to establish the relation between the bursts and flare energy release, and use them to probe physical properties of the energy release site.

118.05 – Self-generated Three Dimensional Turbulence in Magnetic Reconnection Layers Sharply Increases Reconnection Rates

Jeffrey S. Oishi[1], Mordecai-Mark Mac Low[1], David C. Collins[2]
1. American Museum of Natural History, New York, NY, United States. 2. Florida State University, Tallahassee, FL, United States.

Magnetic reconnection is a fundamental plasma process in which magnetic field lines change topology and rapidly convert magnetic energy into thermal energy, which is often directly radiated and thus astrophysically observable. However, the rate at which this process occurs in the classical picture is orders of magnitude too slow to explain solar flares. The recent identification of the plasmoid instability, a super-Alfvenic, high wavenumber instability has fundamentally altered our understanding of reconnection theory by providing a mechanism to greatly speed up reconnection. However, the majority of the work done to date has focused on 2D reconnection layers, assuming symmetry in the plane of the current sheet itself. The plasmoid instability is inherently multi-scale, with a large separation between the global scale of the reconnection layer and the resistive length where the instability grows, making 3D simulations impractical before now. We have begun to use the 3D adaptive mesh refinement code Enzo to resolve the reconnection layer. We show the growth of a secondary instability in the plane of the current sheet that drives a huge increase in the rate of reconnection. Understanding how the saturation of this instability controls the global, 3D structure of reconnection regions is required to predict the observable properties of flares, the mass loading of coronal mass ejections, and the acceleration of charged particles in the corona. This research was partly supported by NSF grant AST10-09802, and used computational resources provided under XSEDE grant TG-AST120045.

118.06 – Reflection and Wave Coupling of Torsional Alfven Waves in 3D Solar Magnetic Flux Tubes

Zdzislaw E. Musielak[1], Krzysztof Murawski[2], Abhishek K. Srivastava[3]
1. Univ. of Texas, Arlington, Arlington, TX, United States. 2. Uni. M. Curie-Sklodowska, Lublin, Poland. 3. ARIES, Nainital, India.

We simulate numerically propagation of nonlinear torsional Alfven waves in 3D magnetic flux tubes embedded in the solar atmosphere with the VAL-C temperature profile that is smoothly extended into the solar corona. The waves are launched at the top of the solar photosphere and their propagation through the solar chromosphere and transition region to the solar corona is studied. We investigate wave reflection in the solar transition region and nonlinear coupling of torsional Alfven waves to magnetoacoustic waves, and use our numerical results to determine the efficiency of energy transfer by these waves to the solar corona and the role played by nonlinear coupling of the waves in heating of different parts of the solar atmosphere. The obtained results are compared to the recent observational data that supplied evidence for the existence of torsional Alfven waves in the solar atmosphere and to the observationally established heating requirements in different parts of the solar atmosphere.

119 – Linking Visualization and Understanding in Astronomy

Plenary Session – Potomac Ballroom A – 06 Jan 2014 11:40 am to 12:30 pm

119.01 – Linking Visualization and Understanding in Astronomy

Alyssa A. Goodman[1]

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.

In 1610, when Galileo pointed his small telescope at Jupiter, he drew sketches to record what he saw. After just a few nights of observing, he understood his sketches to be showing moons *orbiting* Jupiter. It was the visualization of Galileo's observations that led to his understanding of a clearly Sun-centered solar system, and to the revolution this understanding then caused. Similar stories can be found throughout the history of Astronomy, but visualization has never been so essential as it is today, when we find ourselves blessed with a larger wealth and diversity of data, per astronomer, than ever in the past. In this talk, I will focus on how modern tools for interactive "linked-view" visualization can be used to gain insight. Linked views, which dynamically update all open graphical displays of a data set (e.g. multiple graphs, tables and/or images) in response to user selection, are particularly important in dealing with so-called "high-dimensional data." These *dimensions* need not be spatial, even though, e.g. in the case of radio spectral-line cubes or optical IFU data), they often are. Instead, "dimensions" should be thought of as *any* measured attribute of an observation or a simulation (e.g. time, intensity, velocity, temperature, etc.). The best linked-view visualization tools allow users to explore relationships amongst all the dimensions of their data, and to weave statistical and algorithmic approaches into the visualization process in real time. Particular tools and services will be highlighted in this talk, including: Glue (glueviz.org), the ADS All Sky Survey (adsass.org), WorldWide Telescope (worldwidetelescope.org), yt (yt-project.org), d3po (d3po.org), and a host of tools that can be interconnected via the SAMP message-passing architecture. The talk will conclude with a discussion of future challenges, including the need to educate astronomers about the value of visualization and its relationship to astrostatistics, and the need for new technologies to enable humans to interact more effectively with large, high-dimensional data sets.

120 – HAD Business Meeting

Town Hall – National Harbor 5 – 06 Jan 2014 12:45 pm to 01:45 pm

Annual business meeting of the Historical Astronomy Division.

121 – NSF Town Hall

Town Hall – Maryland Ballroom C – 06 Jan 2014 12:45 pm to 01:45 pm

Personnel from the NSF Division of Astronomical Sciences (AST) will discuss the status of their programs. This will include the resolution of the FY 2013 (now past) budget, the status of the FY 2014 budget request, and the impact of these budgets and the AST Portfolio Review on programs of interest to the attendees. The status of major AST construction projects (ALMA, ATST, and LSST) also will be discussed.

122 – The International Astronomical Union: Roles and Goals
Town Hall – Potomac Ballroom D – 06 Jan 2014 12:45 pm to 01:45 pm

Towards the 2015 General Assembly in Honolulu 1) The IAU and science: - introduction to the IAU, including history, current national/individual membership, associates, divisions/commissions/working groups, executive committee, GA & symposia, etc. - importance of global collaboration for advancing the science of astronomy (examples: ALMA, SKA, CTA, next-generation large optical telescopes) - the USA as a special case ? - perspectives 2) The IAU and society - a new Division on "Education, Outreach, and Heritage" - UNESCO/ICOMOS and World Heritage sites - strategic plan and OAD and related bodies, e.g., TF1, TF2, TF3; ROADs - public outreach and legacy of IYA 2009; OAO - public involvement in naming of celestial objects (e.g., Pluto's moons, exoplanets) - perspectives

123 – The NASA Kepler Mission Town Hall: 2014 and Beyond
Town Hall – Potomac Ballroom C – 06 Jan 2014 12:45 pm to 01:45 pm

The NASA Kepler mission is currently operating under a mission extension granted through the NASA Astrophysics Senior Review process. This Town Hall will present a summary of the past year of the Kepler project in order to update the community on the programmatic, technical, and scientific aspects. We will also present our plans for a second mission extension if deemed acceptable by the 2014 NASA Astrophysics Senior Review process. We will highlight the availability of new project and archive products, avenues for community involvement and the Guest Observer program. Please come join us for this town hall, meet the Kepler team, and learn about the future mission plans for both planet discovery and astrophysics using Kepler data. You are encouraged to visit the Kepler mission Science Center at http://keplergo.arc.nasa.gov/

124 – WGLE Town Hall

Town Hall – National Harbor 4 – 06 Jan 2014 12:45 pm to 01:45 pm

The Working Group on LGBTIQ Equality (WGLE) is tasked with promoting equality for lesbian, gay, bisexual, transgender, intersex, and questioning (LGBTIQ) individuals within our profession. Equality begins at home. If you would like your department or institution to be more welcoming to LGBTIQ students and colleagues, join us for a presentation of our new report, "Supporting LGBT+ Physicists and Astronomers: A Best Practices Guide for Departments." Jointly developed by WGLE and the LGBT+ Physicists Organization of the American Physical Society, this document presents ideas for improving the climate in your department, both today and for the long term, tips for addressing hiring and personnel issues, and suggestions for advocacy at the institutional level. Time will be provided for comments and questions from the audience.

125 – Variable Stars
Oral Session – National Harbor 4 – 06 Jan 2014 02:00 pm to 03:30 pm

125.01 – Predicting Fundamental Stellar Parameters From Photometric Light Curves

Adam Miller[1,2], Joseph Richards[1], Joshua S. Bloom[1]
1. UC Berkeley, Berkeley, CA, United States. 2. JPL/Caltech, Pasadena, CA, United States.
Contributing teams: on behalf of a larger team

We present a new machine-learning-based framework for the prediction of the fundamental stellar parameters, Teff, log g, and [Fe/H], based on the photometric light curves of variable stellar sources. The method was developed following a systematic spectroscopic survey of stellar variability. Variable sources were selected from repeated Sloan Digital Sky Survey (SDSS) observations of Stripe 82, and spectroscopic observations were obtained with Hectospec on the 6.5-m Multi-Mirror Telescope. In sum, spectra were obtained for ~9000 stellar variables (including ~3000 from the SDSS archive), for which we measured Teff, log g, and [Fe/H] using the Segue Stellar Parameters Pipeline (SSPP). Examining the full sample of ~67k variables in Stripe 82, we show that the vast majority of photometric variables are consistent with main-sequence stars, even after restricting the search to high galactic latitudes. From the spectroscopic sample we confirm that most of these stellar variables are G and K dwarfs, though there is a bias in the output of the SSPP that prevents the identification of M type variables. We are unable to identify the dominant source of variability for these stars, but eclipsing systems and/or star spots are the most likely explanation. We develop a machine-learning model that can determine Teff, log g, and [Fe/H] without obtaining a spectrum. Instead, the random-forest-regression model uses SDSS color information and light-curve features to infer stellar properties. We detail how the feature set is pruned and the model is optimized to produce final predictions of Teff, log g, and [Fe/H] with a typical scatter of 165 K, 0.42 dex, and 0.33 dex, respectively. We further show that for the subset of variables with at least 50 observations in the g band the typical scatter reduces to 75 K, 0.19 dex, and 0.16 dex, respectively. We consider these results an important step on the path to the efficient and optimal extraction of information from future time-domain experiments, such as the Large Survey Synoptic Telescope. We argue that this machine-learning framework, for which we outline future possible improvements, will enable the construction of the most detailed maps of the Milky Way ever created.

125.02 – Searching Kepler Variable Stars with the Eclipsing Binary Factory Pipeline

Mahmoud Parvizi[1,2], Martin Paegert[2]
1. Austin Peay State University, Clarksville, TN, United States. 2. Vanderbilt University, Nashville, TN, United States.

Repositories of large survey data, such as the Mikulski Archive for Space Telescopes, provide an ideally sized sample from which to identify astrophysically interesting eclipsing binary systems (EBs). However, constraints on the rate of human analysis in solving for the characteristic parameters make mining this data using classical techniques prohibitive. The Kepler data set provides both the high precision simple aperture photometry necessary to detect EBs and a corresponding Kepler Eclipsing Binary Catalog - V3 (KEBC3) of 2,406 EBs in the Kepler filed of view (FoV) as a benchmark. We developed a fully automated end-to-end computational pipeline known as the Eclipsing Binary Factory (EBF) that employs pre-classification data processing modules, a feed-forward single layer perception neural network classifier (NNC), and a subsequent neural network solution estimator (NNSE). This paper focuses on the EBF component modules to include NNC, but excludes the NNSE, as a precursor to a fully automated pipeline that uses solution estimates of characteristic parameters to identify astrophysically interesting EBs. The EBF was found to recover ~94% of KEBC3 EBs contained in the Kepler "Q3" data release where the period is less than thirty days.

125.03 – Update on the asteroseismology of the Kepler field hot pulsating white dwarf

Agnes Kim[1]
1. Penn State University, Dunmore, PA, United States.

In 2012, asteroseismic studies of a pulsating helium atmosphere white dwarf discovered in the Kepler field (KIC 862621) revealed that the star was one of the hottest in its class. Data gathered by Kepler also revealed that a number of the pulsation modes observed in the star were stable over time. Such stable modes can be used to measure a rate of cooling for the star. Combined with interior models of the object, such measurement can help constrain plasmon neutrino emission rates. KIC 862621 is in a temperature range where neutrino cooling contributes to more than half its luminosity. We report on the modeling of the object. The original studies were based on the 5 pulsation periods available at the time. Such a small number of modes only allowed partial constraints on the interior structure. Since then, through continuous observations with Kepler up until the end of the mission, 5 additional independent modes were discovered. We present a new, better constrained asteroseismic study of KIC 862621 based on 10 pulsation periods. Ground observations of the object will continue, yielding a

measurement of the rate of cooling. We will then have the elements in place to help us constrain plasmon neutrino emission rates.

125.04D – The Rejuvenation of RR Lyrae Stars as Precise Distance Indicators

Christopher R. Klein[1]
1. UC Berkeley, Berkeley, CA, United States.

The venerable use of pulsating variables for distance measurements traces back to the dawn of modern astronomy, highlighting the seminal importance of time-domain measurements for astrophysical inquiry. However, dust obscuration at optical wavebands presents a significant impediment both to variable discovery and their use as precision rungs in the cosmic distance ladder. In concert with the recent advent of synoptic near- and mid-infrared imaging capability, allowing for the minimization of dust effects, I embarked on a systematic observational study of RR Lyrae variables leveraging ground- and space-based facilities. Distance measurements derived using the RR Lyrae period-luminosity relation offer precision better than 2% in Galactic regions (within about 100 kpc). As part of this thesis, I present observations and period-luminosity relation fits for 143 RR Lyrae variables spanning 12 wavebands from 0.36 to 22 μm. I use a Bayesian linear model fit to simultaneously constrain the 12 linear relations, the RR Lyrae distance moduli, and the line-of-sight extinction to each star. The mid-infrared period-luminosity relations exhibit substantially reduced scatter, an effect attributed to the associated atmospheric layers oscillating in tighter correlation with the underlying period-radius relation. It is the intrinsically tighter mid-infrared relations that are now enabling distance measurement precision limited only by photometric uncertainty in the variables' mean flux magnitudes. This work is already enabling ongoing Milky Way and Magellanic Cloud studies with the Spitzer Space Telescope, the Wide-Field Infrared Survey Explorer, and multiple ground-based near-infrared facilities. Among these ground-based facilities is RATIR, a six-band quasi-simultaneous optical and near-infrared imager whose development and commissioning I contributed to as part of my thesis work. In the next decade, with local calibrations furnished by GAIA (within 5 kpc), infrared period-luminosity relations of RR Lyrae and Cepheid variables will make possible a more precise calibration of Type Ia SNe luminosities, which in turn is expected to provide a measurement of the Hubble Constant, H_0, with 1% uncertainty.

125.05 – Observations of Suspected RR Lyrae Stars by Undergraduate Students

William L. Powell[1], Stephanie N. Smith[1], Ronald J. Wilhelm[2], Nathan M. De Lee[1]
1. University of Nebraska at Kearney, Kearney, NE, United States. 2. University of Kentucky, Lexington, KY, United States.

I will present a summary of work by my undergraduate students over the past five years aimed at confirming variability of candidate RR Lyrae stars drawn from the Sloan Digital Sky Survey. Selected confirmed variables were observed in pursuit of complete lightcurves.

125.06 – Cepheid period jitter is caused by convective cell

Hilding Neilson[1], Richard Ignace[1]
1. Dept of Physics & Astronomy, East Tennessee State University, Johnson City, TN, United States.

Classical Cepheids are one of the most precise standard candles, however recent Kepler and MOST observations find that Cepheid pulsation periods undergo short term, random-like changes of about twenty to thirty minutes for fundamental-mode Cepheids and longer for first-overtone Cepheids. In this work, we present a model where convective cells in the photosphere perturb the light curve structure, particularly the points of flux minimum and maximum that are used to measure the pulsation period. We find that convection can shift these points and is consistent with observations.

126 – AGN on Sub-kiloparsec Scales

Oral Session – National Harbor 11 – 06 Jan 2014 02:00 pm to 03:30 pm

126.01 – Broad Absorption Line Variability on Multi-Year Timescales in a Large Quasar Sample

W. N. Brandt[1], N. Filiz Ak[1], Patrick B. Hall[2], Donald P. Schneider[1]
1. Penn State Univ., University Park, PA, United States. 2. York University, Toronto, ON, Canada.
Contributing teams: The SDSS-III BAL Variability Team

We have performed a detailed investigation of the variability of 428 C IV and 235 Si IV Broad Absorption Line (BAL) troughs identified in multi-epoch observations of 291 quasars by the Sloan Digital Sky Survey-I/II/III. These observations primarily sample rest-frame timescales of 1-3 yr over which significant rearrangement of the BAL wind is expected. We derive a number of observational results on, e.g., the frequency of BAL variability, the velocity range over which BAL variability occurs, the primary observed form of BAL-trough variability, the dependence of BAL variability upon timescale, the frequency of BAL strengthening vs. weakening, correlations between BAL variability and BAL-trough profiles, relations between C IV and Si IV BAL variability, coordinated multi-trough variability, and BAL variations as a function of quasar properties. We assess implications of these observational results for quasar winds. Our results support models where most BAL absorption is formed within an order-of-magnitude of the wind-launching radius, although a significant minority of BAL troughs may arise on larger scales. We estimate an average lifetime for a BAL trough along our line-of-sight of a few thousand years. BAL disappearance and emergence events appear to be extremes of general BAL variability, rather than being qualitatively distinct phenomena. We derive the parameters of a random-walk model for BAL EW variability, finding that this model can acceptably describe some key aspects of EW variability. The coordinated trough variability of BAL quasars with multiple troughs suggests that changes in "shielding gas" may play a significant role in driving general BAL variability. The good prospects for significantly extending this work will be briefly summarized.

126.02 – On the Absence of Broad Forbidden Lines in the Low Luminosity Active Galactic Nucleus; NGC 3227

Nicholas A. Devereux[1]
1. Embry-Riddle Aeronautical Univ., Prescott, AZ, United States.

The absence of broad [O III] $\lambda\lambda\lambda$4363,4959,5007 forbidden emission lines is the key evidence cited in the published literature for the gas density exceeding the critical density;10^6cm^{-3}, in the broad line region (BLR) of active galactic nuclei (AGN). However, for NGC 3227, an equally valid alternative is that O^{2+} is completely ionized to become O^{3+} in the BLR. Evidence in support of this explanation is a conspicuous, broad, permitted C IV λ1549 recombination emission line which implies the existence of photons with energies ? 48 eV, and overlapping the ionization potential of O^{2+}. Consequently, according to this interpretation, the absence of broad [O III] forbidden emission lines is due to high ionization rather than high gas density. Thus, the gas density in the BLR of NGC 3227 may be less than 10^6 cm^{-3}, commensurate, in fact, with a model in which the BLR is essentially a large, steady-state, inflow that is photoionized by the central AGN.

126.03 – The Broad Line Region in AGNs: Structure, Physics, and the f Factor

Catherine Grier[1], Bradley M. Peterson[1, 2], Paul Martini[1, 2], Richard W. Pogge[1], Anna Pancoast[3], Tommaso Treu[3], Linda C. Watson[4]
1. The Ohio State University, Columbus, OH, United States. 2. Center for Cosmology and AstroParticle Physics, Columbus, OH, United States. 3. UCSB, Santa Barbara, CA, United States. 4. Harvard Center for Astrophysics, Cambridge, MA, United States.

We present recent results in an effort to investigate the structure of the broad line region in active galactic nuclei (AGNs) using reverberation mapping data. AGNs provide our only means for exploring the black hole (BH) population outside the local universe. To measure black hole masses (MBH) in AGNs, we use the broad line region (BLR) by assuming that the motion of the emitting gas is dominated by the gravity of the BH. Virial MBH measurements can be made using the resulting Doppler-broadened emission lines: MBH = fR?V^2/G. R is the distance of the emitting gas from the BH, ?V is the velocity dispersion of the emitting gas, obtained from the width of the emission line, and f is a dimensionless factor that accounts for the geometry and orientation of the BLR. Because the BLR is unresolvable, the true value of f in for each object is unknown. Typically, an average virial factor f is used, calculated by assuming that AGNs follow the same MBH--? relation as quiescent galaxies. Our inability to directly observe the structure of the BLR and is a major source of uncertainties in MBH measurements. To learn about BLR structure, we must rely on either reverberation mapping techniques or microlensing of gravitationally lensed quasars. We have been working on various aspects of this problem using high-quality reverberation-mapping data from various observing campaigns based at MDM Observatory on Kitt Peak. Results from these reverberation efforts have a broad impact on our understanding of AGN physics as well as on all MBH measurements in AGNs that provide

a basis for galaxy evolution and AGN feedback models.

126.04 – The NLR Size - IR Luminosity Relationship: An Upper Limit on the Size of the Narrow-Line Region?

Kevin Hainline[1], Ryan C. Hickox[1], Jenny E. Greene[2], Adam D. Myers[3], Nadia L. Zakamska[4], Guilin Liu[4]

1. Dartmouth College, Hanover, NH, United States. 2. Princeton University, Princeton, NJ, United States. 3. University of Wyoming, Laramie, WY, United States. 4. Johns Hopkins University, Baltimore, MD, United States.

We examine the spatial extent of the narrow-line regions (NLRs) of a large sample of local active galaxies. While we see a shallow slope in the relationship between NLR size and [OIII] luminosity (L[OIII]), we also explore how the NLR size scales with a more direct measure of instantaneous AGN power using mid-IR photometry from WISE. IR emission probes warm to hot dust near the central black hole and so, unlike L[OIII], it does not depend on the properties of the NLR. We calculate a power-law relationship between NLR size and 8 micron luminosity (L8µm) that is significantly steeper than that observed for NLR size and L[OIII]. We find that the size of the NLR goes approximately as $L8µm^{1/2}$, as expected from the simple scenario of constant-density clouds illuminated by a central ionizing source. We further see tentative evidence for a turnover at the high luminosity end of the relationship between NLR size and L8µm, and propose that we are seeing a limiting NLR size of 10 20 kpc, beyond which the availability of gas to ionize becomes too low. We find that L[OIII] is proportional to $L8µm^{1.4}$, consistent with a picture in which the [OIII] luminosity is dependent on the volume of the NLR. Together, these results indicate that high-luminosity quasars have a strong effect in ionizing the available gas throughout their host galaxies.

126.05 – Long-term Absorption Variation in AGN: A High-resolution Study of the Seyfert Galaxy NGC 3783

Amy Scott[1]

1. The Pennsylvania State University, University Park, PA, United States.

We present the results of recent Chandra HETGS and HST COS observations of the nearby Seyfert 1 galaxy NGC 3783, which exhibits a strong X-ray warm absorber (e.g. Kaspi et al.) and physically related and kinematically varying UV absorbers (Gabel et al.). We compare our new observations to archival data from 2001, allowing a unique investigation into the long-term variations of the absorption over a 12 year period. Comparing the overall continua, individual absorption line profiles, and stacked line profiles in velocity space allows us to place constraints on the column density, ionization state and outflow velocity of the absorbers. We discuss the implications of structure, location and kinematic changes of the absorbers in the context of outflow models and the wider effects of AGN on their host galaxies.

126.06 – Black Hole Spin Properties of 130 AGN

Ruth A. Daly[1]

1. Penn State University, Reading, PA, United States.

Supermassive black holes are characterized by their mass and spin. Black hole spins can be estimated for sources with outflows when the black hole mass and outflow power can be empirically determined. Samples of radio galaxies and quasars for which the outflow power and black hole mass have been determined are identified leading to a sample of 130 AGN for which spins can be determined; the sample includes 71 FRII radio galaxies, 30 FRII radio loud quasars, and 29 (primarily FRI) radio sources associated with CD galaxies. Typical spin values range from about 0.1 to 1. The FRII sources are fairly evenly distributed in redshift with redshifts between about zero and two. The spin properties of quasars will be compared with those of radio galaxies, and the redshift evolution of the radio galaxies, quasars, and total sample will be discussed.

126.07 – The Black Hole in the Compact, High-dispersion Galaxy NGC 1271

Jonelle Walsh[1], Remco van den Bosch[2], Karl Gebhardt[1], Akin Yildirim[2], Kayhan Gultekin[3], Douglas O. Richstone[3]

1. The University of Texas - Austin, Austin, TX, United States. 2. Max Planck Institute for Astronomy, Heidelberg, Germany. 3. University of Michigan, Ann Arbor, MI, United States.

Correlations linking the mass of the black hole in the centers of galaxies to bulge properties have been clearly established over the past decade; however there still remain major open questions, particularly concerning the sparsely populated upper end of the black hole mass distribution. Through a large survey with the Hobby Eberly Telescope at McDonald Observatory, we have identified a sample of ideal galaxies for studying the upper end of the black hole mass scaling relations. These galaxies are compact, rapidly rotating, and have low luminosities for their very large stellar velocity dispersions, in sharp contrast to the objects typically found at the high end of the black holes mass - bulge relationships. In this talk, we focus on

one galaxy in the sample: the nearby S0 galaxy NGC 1271. We present laser guide star adaptive optics observations of NGC 1271 with the integral field spectrograph NIFS on the Gemini North telescope. By combining the high spatial resolution stellar kinematics measured from the NIFS observations with imaging and large-scale stellar kinematics, we construct orbit-based stellar dynamical models. We will present results of the dynamical modeling, emphasizing the constraints on the black hole mass, and place NGC 1271 on the black hole mass - host galaxy relationships.

126.08D – Intervening broad-line region clouds' effects on the optical/ultraviolet spectrum

Ye Wang[1], Gary J. Ferland[1], Chen Hu[2], Jian-Min Wang[2], Pu Du[2]

1. Department of Physics and Astronomy, University of Kentucky, Lexington, KY, United States. 2. Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China.

Recent x-ray observations of Mrk 766 suggest that broad emission line region clouds cross our line of sight and produce variable x-ray absorption. Here we investigate what optical/ultraviolet spectroscopic features would be produced by such "Intervening BLR Clouds" crossing our line of sight to the accretion disk, which is the source of the optical/UV continuum. Although the emission spectrum produced by intervening clouds is identical to the standard BLR model, they may produce absorption features on the optical or UV continuum. We find that single clouds will have little effect on the optical/UV spectrum because BLR clouds are likely to be much smaller than the accretion disk. This is unlike the X-ray case, where the radiation source is considerably smaller. However, an ensemble of intervening clouds will produce spectroscopic features in the FUV including a strong depression between the Lyman limit and Lyα. The amount of the depression will indicate the line-of-sight covering factor of clouds, an unknown quantity that is important for the ionization of the intergalactic medium and the energy budget of AGN. Comparison with observations suggests that the SED of Mrk 766 may be affected by intervening BLR clouds and Intervening BLR Clouds may exist in most of AGNs.

127 – Cosmology & CMB II
Oral Session – Potomac Ballroom D – 06 Jan 2014 02:00 pm to 03:30 pm

127.01 – Testing Quantum Mechanics with Observations of Causally Disconnected Cosmological Events

Andrew S. Friedman[1, 2], David I. Kaiser[1], Jason Gallicchio[3], Alan H. Guth[1]
1. Massachussetts Institute of Technology, Center for Theoretical Physics, Cambridge, MA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. University of Chicago, Kavli Institute for Cosmological Physics, Chicago, IL, United States.

We discuss a thought experiment which would leverage cosmology to test quantum mechanics using astronomical observations. Specifically, we aim to close the "settings-independence" loophole in experimental tests of Bell's inequality by choosing the detector settings (e.g. polarizer orientations) using real-time observations of causally disconnected cosmic sources. This would help close one of the most important remaining Bell test loopholes whereby a local hidden variable theory could mimic the quantum predictions if the experimental settings choices shared even a small correlation due to unknown local causal influences prior to the experiment. The talk will focus on the theoretical cosmology constraints needed to choose optimal sources for such an experiment, describing general conditions for pairs of cosmic events with arbitrary redshifts and angular separations to have shared causal pasts in Friedman-Lemaitre-Robertson-Walker universes with arbitrary curvature, including flat, dark energy dominated, accelerating universes like our own. While causally disjoint patches of the cosmic microwave background radiation at redshift z ~ 1090 could be used to set the detectors, z > 3.65 quasars observed at optical wavelengths are arguably the optimal candidate source pairs using present technology that meet the condition of having no shared causal past since the end of any period of inflation, 13.82 Gyr ago. Results are illustrated for our universe with causal structure animations to help visualize the intersections of past light cones for arbitrary event pairs.

127.02 – Effects of Local Inhomogeneity on Cosmological Observables

John Hornstein[1]
1. , Silver Spring, MD, United States.

Initial results are presented from a program to characterize the effect of spatial inhomogeneity on the cosmological expansion and development of structure, and on cosmological measurements. The analysis uses simple generalizations of the quasi-Cartesian version of the Robertson-Walker metrics, to enable a significant part of the analysis to be performed analytically. The inclusion of spatial inhomogeneity allows the analytic and semi-analytic study of spatially periodic models, with cosmologically expanding cells, such as those that are used in large scale numerical simulations. For a spatially periodic metric, Einstein's equation yields coupled nonlinear equations for the evolution of the Fourier amplitudes of the spatial variations in energy density and pressure. The evolving spatial variations can also produce offsets and scatter in the look-back time, luminosity distance, and angular diameter distance for sources that all have the same cosmological red shift. The effects on the cosmological observables are conceptually related to large scale gravitational lensing, and also to the Sachs-Wolfe effects.

127.03D – New Constraints on the Amplitude of Cosmic Density Fluctuations and Intracluster Gas from the Thermal SZ Signal Measured by the Atacama Cosmology Telescope (ACT) and Planck

James Hill[1], David N. Spergel[1]
1. Princeton University, Princeton, NJ, United States.
Contributing teams: Atacama Cosmology Telescope Collaboration

Galaxy clusters form from the rarest peaks in the initial matter distribution, and hence are a sensitive probe of the amplitude of density fluctuations ($?_8$), the amount of matter in the universe, and the growth rate of structure. Galaxy clusters have the potential to constrain dark energy and neutrino masses. However, cluster cosmology is currently limited by systematic uncertainties due to poorly understood intracluster gas physics. I will present new statistical approaches to understand clusters and improve their cosmological constraining power through the thermal Sunyaev-Zel'dovich (tSZ) effect. First, I will describe the first detection of the cross-correlation of the tSZ signal reconstructed from Planck data with the large-scale matter distribution traced by the Planck CMB lensing potential. This statistic measures the amount of hot gas found in moderately massive groups and clusters (M ~ 10^{13} - $10^{14.5}$ M_{sun}), a mass scale below that probed by direct cluster detections. Second, I will describe the first measurement of the PDF of the tSZ field using ACT 148 GHz maps. This measurement contains information from all (zero-lag) moments of the tSZ field, beyond simply the 2- or 3-point functions. It is a very sensitive probe of $?_8$ and may also provide a method with which to break the degeneracy between $?_8$ and uncertainties in the physics of the intracluster gas.

127.05 – Micro-Jy imaging at 150 MHz for the LOFAR EoR project

Michiel A. Brentjens[1], Sarod Yatawatta[1], Vishambar Pandey[1], Vibor Jelic[1], A. G. de Bruyn[1, 2], Leon Koopmans[2], Saleem Zaroubi[2]
1. Astron, Dwingeloo, Drenthe, Netherlands. 2. Kapteyn Astronomical Institute, University of Groningen, Groningen, Groningen, Netherlands.

In its search for neutral hydrogen emission from the Epoch of Reionization, LOFAR has by now accumulated more than 600 hours of radio interferometric data, spread across three target windows: the north celestial pole, 3C 196, and ELAIS-N1. During the past year we improved our calibration and searched for -- and eliminated -- systematic effects in our data and procedures. Although we have not yet detected the signal we are looking for, we have produced by far the deepest and cleanest maps ever made between 115 and 185 MHz. Our 6 arc-second resolution maps reach noise levels between 25 and 80 micro-Jy per beam. We detect thousands of radio sources per field, and find varying amounts of diffuse Galactic polarization in all our target windows. We will present the maps and discuss the most important issues we encountered in producing them.

127.06 – The Stratospheric Kinetic Inductance Polarimeter (SKIP)

Daniel Flanigan[1], Peter Ade[4], Derek Araujo[1], Kristi J. Bradford[2], Daniel Chapman[1], George Che[2], Peter Day[5], Joy Didier[1], Simon Doyle[4], Hans Eriksen[8], Christopher E. Groppi[2], Seth N. Hillbrand[1], Bradley Johnson[1], Glenn Jones[1, 7], Michele Limon[1], Philip Mauskopf[2], Heather McCarrick[1], Amber D. Miller[1], Tony Mroczkowski[6], Britt Reichborn-Kjennerud[1], Brian Smiley[1], Joshua Sobrin[1], Ingunn K. Wehus[3, 5], Jonas Zmuidzinas[3]
1. Columbia University, New York City, NY, United States. 2. Arizona State University, Phoenix, AZ, United States. 3. California Institute of Technology, Pasadena, CA, United States. 4. Cardiff University, Cardiff, Wales, United Kingdom. 5. Jet Propulsion Laboratory, Pasadena, CA, United States. 6. Naval Research Laboratory, Washington, DC, United States. 7. National Radio Astronomy Observatory, Charlottesville, VA, United States. 8. University of Oslo, Oslo, Oslo, Norway.

We discuss the Stratospheric Kinetic Inductance Polarimeter (SKIP). SKIP is a proposed balloon-borne experiment designed to study the cosmic microwave background, the cosmic infrared background, and Galactic dust emission by observing 1100 square degrees of sky in the Northern Hemisphere with launches from Kiruna, Sweden. The instrument contains 2317 single-polarization, horn-coupled, aluminum lumped-element kinetic inductance detectors (LEKIDs), which will be maintained at 100 mK by an adiabatic demagnetization refrigerator. The polarimeter will operate in two configurations, one sensitive to a spectral band centered on 150 GHz and the other sensitive to 260 and 350 GHz bands. The detector readout system is based on the ROACH-1 board, and the detectors will be biased below 300 MHz. The detector array is fed by an F/2.4 crossed-Dragone telescope with a 500 mm aperture yielding a 15 arcminute full-width half-maximum beam at 150 GHz. To minimize detector loading and maximize sensitivity, the entire optical system will be cooled to 1 K. Linearly polarized sky signals will be modulated with a metal-mesh half-wave plate that is mounted at the telescope aperture and is rotated on a superconducting magnetic bearing. The observation program consists of two or more five-day flights, and 150 GHz observations are planned to begin in 2017.

128 – Dynamics and Habitability of Exoplanets - What have we learned from Kepler?

Special Session – Potomac Ballroom A – 06 Jan 2014 02:00 pm to 03:30 pm

We now know that many, and perhaps most, planetary systems contain multiple planets with periods from a few to ~100 days, and masses intermediate between those of Earth and Neptune, as seen in the Kepler multi-transiting systems. At the same time, as the Kepler data continue to be processes, planets with longer periods are being discovered, reaching into the habitable zones of their host stars. The three invited speakers in this session will explore broadly the theoretical implications of these recent discoveries.

128.01 – Overstable Librations can account for the Paucity of Mean Motion Resonances among Exoplanet Pairs

Hilke Schlichting[1]

1. MIT, Cambridge, CA, United States.

Only a few percent of planet pairs are in close proximity to a resonance. However, predicted migration rates (parameterized by $?\_n = n/|\dot n|$) imply that during convergent migration most planets would have been captured into first order resonances. I will show that eccentricity damping (parameterized by $?\_e = e/|\dot e|$) offers a plausible resolution. Estimates suggest $?\_e/?\_n \sim (h/a)^2 \sim 0.01$, where h/a is the ratio of disk thickness to radius. Together, eccentricity damping and orbital migration give rise to an equilibrium eccentricity, $e\_eq \sim (?\_e/?\_n)^{(1/2)}$. Capture is permanent provided $e\_eq \lesssim \mu^{(1/3)}$, where μ denotes the planet to star mass ratio. But for $e\_eq \gtrsim \mu^{(1/3)}$, capture is only temporary because librations around equilibrium are overstable and lead to passage through resonance on timescale $?\_e$. Most Kepler planet pairs have $e\_eq > \mu^{(1/3)}$. Since $?\_n \gg ?\_e$ is the timescale for migration between neighboring resonances, only a modest percentage of pairs end up trapped in resonances after the disk disappears. Thus the paucity of resonances among Kepler pairs should not be taken as evidence for in situ planet formation or the disruptive effects of disk turbulence.

128.02 – Reaching into the Habitable Zones of Kepler Stars

Stephen R. Kane[1], Dawn M. Gelino[2], Natalie R. Hinkel[1]

1. San Francisco State University, San Francisco, CA, United States. 2. California Institute of Technology, Pasadena, CA, United States.

The field of exoplanets has rapidly expanded from the exclusivity of exoplanet detection to include exoplanet characterization. A key step towards this characterization is the determination of which planets occupy the Habitable Zone (HZ) of their host stars. As the Kepler data continues to be processed, the orbital period sensitivity is increasing and there are now numerous exoplanets known to occupy the HZ of their host stars. In this talk I will describe the properties of the HZ, the dependence on the spectral type properties, and the current state of exoplanet detections in the HZ. I will present several case studies of HZ Kepler planets, including circumbinary planets for which the HZ is a time-dependent function. Finally, I will relate HZ results to the calculation of eta_Earth and eta_Venus.

128.03 – Lessons From Kepler

Yoram Lithwick[1]

1. Northwestern University, Evanston, IL, United States.

The Kepler space telescope has discovered hundreds of planetary systems. Many of the systems' properties are completely unexpected, based on what we thought we understood about planet formation. I will discuss some recent lessons learned, including the masses and eccentricities of over a hundred planets from transit time variations. I will also discuss what I think this and other puzzles might be teaching us about how these peculiar planetary systems formed and evolved.

129 – Evolution of Elliptical Galaxies and Black Holes

Oral Session – Maryland Ballroom D – 06 Jan 2014 02:00 pm to 03:30 pm

129.01 – A New Population of Recently Quenched Elliptical Galaxies in the SDSS

Daniel H. McIntosh[1], Cory Wagner[2], Andrew Cooper[3], Eric F. Bell[4], Dusan Keres[5], Frank C. van den Bosch[6], Anna Gallazzi[7], Tim Haines[8], Justin Mann[9], Anna Pasquali[10]
1. University of Missouri-Kansas City, Kansas City, MO, United States. 2. Queens University, Kingston, ON, Canada. 3. University of North Carolina, Chapel Hill, Chapel Hill, NC, United States. 4. University of Michigan, Ann Arbor, MI, United States. 5. University of California, San Diego, San Diego, CA, United States. 6. Yale University, New Haven, CT, United States. 7. INAF-Osservatorio Astrofisico di Arcetri, Firenze, Italy. 8. University of Wisconsin-Madison, Madison, WI, United States. 9. University of Kansas, Lawrence, KS, United States. 10. University of Heidelberg, Heidelberg, Germany.

The importance of different physical processes that add new elliptical galaxies to the quiescent population remains poorly constrained. As such, it is critical to investigate samples that are transitioning from the star-forming blue cloud to the red sequence. Using a comprehensive catalog of unusually blue ellipticals with Mstar > 10^10 Msun and 0.01<z<0.08 from the SDSS, we study published fiber spectra diagnostics and identify a unique population of 172 recently quenched ellipticals (RQEs). These redward transitioning galaxies have sufficient numbers above 2.5x10^10 Msun to account for more than half of the expected quiescent growth at late cosmic time assuming this phase lasts 0.5Gyr. The bulk of these galaxies have properties that are consistent with recent major merging rather than minor 'frosting' events, yet few involved a starburst strong enough to produce an E+A signature. The preferred environment of RQEs agrees well with the `small group scale' predicted for maximally efficient spiral merging onto their halo center and rules out satellite-specific quenching processes. Despite an increased association with Seyfert activity, RQEs cannot provide direct quenching-feedback connections owing to very short AGN timescales compared to A-star lifetimes. Instead, it is possible that most RQEs were quenched by a hot atmosphere impeding efficient gas cooling in their small host halos. In this scenario, the high incidence of Seyfert and LINER activity in both RQEs and their plausible descendents may supply the necessary maintenance heating. Further exploration of these galaxies holds promise for illuminating the complex physics of quenching and its role in galaxy evolution.

129.02D – Diagnosing the Formation of Elliptical Galaxies

Gregory F. Snyder[1,2], Lars E. Hernquist[2]
1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Harvard University, Cambridge, MA, United States.

A challenge in extragalactic astronomy is that we cannot watch what happens to galaxies before and after they are observed. In particular, it remains debated whether galaxy mergers or internal processes drive supermassive black hole growth, trigger luminous starbursts, and shape the population of galaxies we see today. However, given increasingly available computer resources, it is now possible to predict how galaxies might evolve according to a huge variety of observations. With hydrodynamical simulations followed by dust radiative transfer, I examine the formation of elliptical galaxies through three putative phases: dust-obscured starburst, transition object, and red spheroid. I build spatially and spectrally resolved models to analyze diagnostics of essential processes and evaluate the implications of galaxy interactions. I derive an idealized JWST-accessible mid-infrared diagnostic using mock spectra from simulations of merger-induced starbursts. I use similar models to reconcile the numbers of optically selected post-starburst galaxies in the local universe with expectations given independent estimates of the galaxy merger rate. To conclude, I outline an approach to build a "mock observatory" from large-volume cosmological hydrodynamical simulations, with which observations of many types can be brought to bear to constrain the physics of galaxy formation.

129.03 – Evidence of Inside-out Multi-stage Formation History in UV-bright Early Type Galaxies Observed in the Mid-IR

Sara M. Petty[1], James D. Neill[2], Tom Jarrett[3], Andrew Blain[4], Duncan Farrah[1], Robert M. Rich[5], Chao-Wei Tsai[2], Dominic J. Benford[6], Carrie Bridge[2], Sean E. Lake[5], Frank J. Masci[7], Edward L. Wright[5]
1. Physics, Virginia Tech, Blacksburg, VA, United States. 2. Caltech, Pasadena, CA, United States. 3. University of Cape Town, Rondebosch, Cape Town, South Africa. 4. University of Leicester, Leicester, Leicestershire, United Kingdom. 5. UCLA, Los Angeles, CA, United States. 6. NASA, Goddard Space Flight Center, Greenbelt, MD, United States. 7. IPAC, Caltech, Pasadena, CA, United States.

Contributing teams: WISE

The origin of significant UV emission in quiescent early type galaxies (ETGs) is currently still debated, and strongly tied to a multi-epoch evolutionary process where much of the information is lost after progressing well beyond relaxation timescales. In order to address this topic, stellar synthesis and galaxy evolution must be disentangled, which can be more pragmatically done with well-resolved multi-wavelength images of nearby ETGs. We explore the radial distribution of FUV-NUV, NUV-r, and NUV-IR colors (GALEX, SDSS, and WISE) in a selection of nearby E/S0-type galaxies. Comparing these colors with stellar synthesis models, we find strong color gradients with the outer radii bluer than the inner half-light radii by ~1 magnitude, and account for it with an extreme horizontal branch fraction increase of 0.25 with radius. We estimated the average ages and determine that outer regions are likely to have formed ~1 Gyr after the inner regions. The results support inside-out formation: rapid star formation within the core at early epochs (>4 Gyr ago) and at least one later stage starburst event coinciding with z~1.

129.04 – Dwarf Galaxies with Active Massive Black Holes

Amy E. Reines[1], Jenny E. Greene[2], Marla C. Geha[3]
1. National Radio Astronomy Observatory, Charlottesville, VA, United States. 2. Princeton University, Princeton, NJ, United States. 3. Yale University, New Haven, CT, United States.

Supermassive black holes (BHs) live at the heart of essentially all massive galaxies with bulges, power AGN, and are thought to be important agents in the evolution of their hosts. However, the birth and growth of the first supermassive BH "seeds" is far from understood. While direct observations of these distant BHs in the infant Universe are unobtainable with current capabilities, massive BHs in present-day dwarf galaxies can place valuable constraints on the masses, formation path, and hosts of supermassive BH seeds. Using optical spectroscopy from the SDSS, we have systematically assembled the largest sample of dwarf galaxies hosting active massive BHs to date. These dwarf galaxies have stellar masses comparable to the Magellanic Clouds and contain some of the least-massive supermassive BHs known.

129.05D – Modeling the Co-Evolution of Black-Holes and Galaxies Across Cosmic Time

Daniel Angles-Alcazar[1]
1. University of Arizona, Tucson, AZ, United States.

There is ample observational evidence for a close connection between the formation and evolution of massive black holes and the evolution of their host galaxies. Recent models of black hole growth in a cosmological context have forwarded a paradigm in which black hole growth is self-regulated by feedback from the accretion process itself. Here I will describe an alternative scenario consistent with available observations in which the transport of angular momentum in the galaxy by gravitational instabilities regulates the long-term co-evolution of black holes and star-forming galaxies. By combining cosmological hydrodynamic simulations of galaxy formation together with analytic models of black hole accretion, I will show that torque-limited growth yields black holes and host galaxies evolving on average towards the observed scaling relations, with no need for mass averaging through mergers or additional self-regulation processes. Strong outflows from the accretion disk are required to provide a significant mass loss but do not need to couple to galaxy-scale gas in order to regulate black holes in a non-linear feedback loop. I will discuss the main implications of this scenario in the context of current observations, including predictions for the distribution and evolution of Eddington ratios and the inferred connection between star formation and nuclear activity in star-forming galaxies.

129.06 – Systematic Errors in Black Hole Mass Measurements

Nicholas J. McConnell[1]
1. IfA, University of Hawaii, Honolulu, HI, United States.

Compilations of stellar- and gas-dynamical measurements of supermassive black holes are often assembled without quantifying systematic errors from various assumptions in the dynamical modeling processes. Using a simple Monte-Carlo approach, I will discuss the level to which different systematic effects could bias scaling relations between black holes and their host galaxies. Given that systematic errors will not be eradicated in the near future, how wrong can we afford to be?

130 – Evolution of Star Formation and Dust in Galaxies
Oral Session – National Harbor 2 – 06 Jan 2014 02:00 pm to 03:30 pm

130.01 – Connecting Dust and Galaxy Properties at High Redshift

Daniel A. Perley[1], Thomas Kruehler[2], Mansi M. Kasliwal[3], Jochen Greiner[4], Patricia Schady[4], Darach Watson[5], Tayyaba Zafar[6], Joshua S. Bloom[7], Adam Morgan[7], Stephen B. Cenko[8], Andrew J. Levan[9], Nial R. Tanvir[10]

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The extinction curves of interstellar dust in the local Universe show significant diversity along different sightlines and between different galaxies, in particular with regards to the presence (and relative strength) of the 2175 Angstrom bump feature. These locally-derived extinction curves are often used to correct for the effects of dust in the SEDs of galaxies at high redshift (z>1), but this process is quite uncertain. We use a large sample of high-z GRBs with well-studied afterglows permitting measurement of the extinction curve (including the presence/absence and relative strength of the 2175 Angstrom feature) along the burst sightline to explore the connection between extinction and bulk galaxy properties at high redshift. While host properties are strongly correlated the amount of dust seen along the GRB sightline (more obscured GRBs are located within more massive hosts), the nature of the dust does not show strong correlations with the host's overall properties. In particular, we demonstrate that the 2175 Angstrom feature can survive in galaxies with very high specific star-formation rate (and therefore a strong UV radiation field) in some cases, as well as within more quiescently star-forming galaxies. This suggests that dust properties within high-redshift galaxies may be influenced more by local phenomena than global ones and that, as in the Milky Way, extinction curves may differ substantially along different sightlines within high-z galaxies as well as between different galaxies.

130.02D – How Environment Affects Star Formation: Tracing Activity in High Redshift Galaxy Clusters

Stacey Alberts[1], Alexandra Pope[1], Mark Brodwin[2], David W. Atlee[3], Yen-Ting Lin[4], Ranga-Ram Chary[11], Arjun Dey[3], Peter R. Eisenhardt[5], Daniel Gettings[6], Anthony H. Gonzalez[6], Buell Jannuzi[12], Conor Mancone[6], John Moustakas[7], Gregory F. Snyder[8], S. A. Stanford[9], Daniel Stern[5], Benjamin J. Weiner[12], Gregory Zeimann[10]

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The emerging picture of the evolution of cluster galaxies indicates that the epoch of z>1 is a crucial period of active star formation and mass assembly in clusters. In this dissertation, I leverage a uniformly-selected cluster sample from the IRAC Shallow Cluster Survey (ISCS) with Herschel imaging to analyse the star formation (SF) activity in cluster galaxies over the past ten billion years. This analysis is two-fold: 1) using 274 clusters across the 9 square degree Bootes field, I perform a stacking analysis of mass-limited samples of cluster and field galaxies using wide-field Herschel observations over a long redshift baseline, z=0.3-1.5. I find that the average SF activity in cluster galaxies is evolving faster than in the field, with field-like SF in the cluster cores and enhanced SF activity in the cluster outskirts at z>1.2. By further breaking down my analysis by galaxy mass and type, I determine which mechanisms are capable of driving this evolution. 2) I use unique, deep Herschel imaging of 11 spectroscopically-confirmed clusters from z=1.1-1.8 to study the properties of individual infrared bright cluster galaxies as a function of redshift and cluster-centric radius. Combined with ancillary data, I determine the star formation, dust, and AGN properties of the most active cluster galaxies and tie the evolution of these properties back to the environment by comparing to field populations. By combining these two approaches, I constrain cluster galaxy properties during a pivotal epoch of dust-obscured star formation activity and mass assembly in some of the most extreme structures in the Universe.

130.03D – Chemical Evolution of Star-Forming Galaxies

Harus Zahid[1]

1. University of Hawaii at Manoa, Honolulu, HI, United States.

The abundance of heavy elements is a fundamental property of galaxies. Understanding the chemical evolution of galaxies is crucial for developing a comprehensive theory of galaxy formation and evolution. The gas-phase oxygen abundance, i.e. metallicity, of a galaxy is set by the interplay between star formation and gas flows. Metals are dispersed into the interstellar medium by stellar winds and supernovae. Metals accumulate in the interstellar medium of star-forming galaxies and provide a record of star-formation. However, inflows of unenriched gas into galaxies and metal-rich outflows of gas from galaxies can both reduce the metallicity. Thus, measurements of the metallicity across cosmic time provide important constraints for understanding the cycling of gas through galaxies as they build their stellar mass and evolve. I have measured the chemical evolution of galaxies over the last 10 billion years of cosmic time. These measurements provide a coherent picture of how galaxies enrich as they build their stellar mass. Using these measurements, I have conducted the first census of oxygen in star-forming galaxies. The oxygen census reveals that over their lifetime, star-forming galaxies expel a substantial fraction of the oxygen they produce in outflows. I will show that the mass of oxygen missing from galaxies is consistent with recent observational estimates of the mass of oxygen in halos of gas ubiquitously surrounding local star-forming galaxies. The mass of oxygen missing from galaxies provides one of the most robust empirical constraints for the total mass lost via outflows in galaxies. The properties of mass loss by outflows is one of the greatest uncertainties in theoretical models of galaxy formation and evolution. I will show that the amount of mass loss currently implemented in theoretical models is 1-2 orders of magnitude larger than the empirical estimates for mass loss from the oxygen census. The discrepancy between empirical and theoretical constraints for the amount of mass loss has important implications for our understanding of galaxy evolution. I will end with three possible resolutions to this discrepancy.

130.04 – ALMA Dust Continuum for ISM Mass Estimates in High-z Galaxies

Nicholas Scoville[1], Herve Aussel[1], Kartik Sheth[1], Kimberly S. Scott[1], David B. Sanders[1], Rob Ivison[1], Alexandra Pope[1], Peter L. Capak[1], Swarnima Manohar[1], Jeyhan S. Kartaltepe[1], Simon Lilly[1]

1. Caltech, Pasadena, CA, United States.

The use of submm dust continuum emission to probe the mass of dust and ISM in galaxies is empirically calibrated using samples of local star forming galaxies, Planck observations of the Milky Way and high redshift submm galaxies (SMGs). All of these objects suggest a similar calibration, strongly supporting the view that the Rayleigh-Jeans (RJ) tail of the dust emission can be used as an accurate and very fast probe of the ISM in galaxies. We present ALMA Cycle 0 observations of the Band 7 (350 GHz) dust emission in 107 galaxies from z = 0.2 to 2.5. Three samples of galaxies with a total of 101 galaxies were stellar mass-selected from COSMOS to have $M\_* \sim 10^{11} M\_sun$: 37 at z ~ 0.4, 33 at z~ 0.9 and 31 at z= 2. A fourth sample with 6 IR luminous galaxies at z = 2 was observed for comparison with the purely mass-selected samples. From the fluxes detected in the stack images, we find that the ISM content has decreased a factor 6 from 1 - 2x10^10M_sun at both z = 2 and 0.9 down to 2x10^9 M_sun at z=0.4. The IR luminous sample at z=2 shows a further 4x increase in MISM compared to the equivalent non-IR bright sample at the same redshift. The gas mass fractions are ~2, 12, 14 and 53% for the four samples.

130.05D – Star Formation in Cosmological N-body Simulations

Ferah Munshi[1]

1. University of Washington, Seattle, WA, United States.

The primary focus of my thesis work is to study star formation using a series of high resolution cosmological N-body simulations. Specifically, I have studied the total stellar-to-halo mass ratio as a function of halo mass for a new sample of simulated field galaxies using fully cosmological, LCDM, high resolution SPH + N-Body simulations carried to the present time. I find there is extremely good agreement between the simulations and predictions from the statistical Halo Occupation Distribution model presented in Moster et al. (2012). This is due to a combination of systematic factors: a) gas outflows that reduce the overall SF efficiency and b) estimating the stellar masses of simulated galaxies using artificial observations and photometric techniques similar to those used in observations. My analysis suggests that stellar mass estimates based on photometric magnitudes underestimate the contribution of old stellar populations to the total stellar mass, leading to stellar mass errors of up to 50% for individual galaxies and highlight the importance of using proper techniques to compare simulations. Additionally, my work examines the pressure of the star-forming interstellar medium (ISM) of simulated high-resolution Milky-Way sized spiral galaxies, using a kinematic decomposition of these galaxies into present-day bulge and disk components. I find that the typical pressure of the star-forming ISM in the present-day bulge is higher than that in the present-day disk by an order of magnitude. Additionally, the pressure of the star-forming ISM in the early protogalaxy is on average, higher than ISM pressures after z = 2. This explains the why the bulge forms at higher pressures: the disk assembles at lower redshift, when the ISM is generally lower pressure and the bulge forms at higher redshift when the ISM is at higher pressures. If ISM pressure and IMF variation are tied together as suggested in studies like Conroy & van Dokkum (2012), these results could indicate a time-dependent IMF in Milky-Way like systems.

130.06 – Galaxy formation in preheated IGM

Yu Lu[1]

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If the IGM is heated up to a finite entropy by early starbursts or feedback processes since z~3, galaxy formation in the preheated medium at late times will be affected. The accretion rate of baryonic matter of low-mass halos can be substantially reduced and the halo gas distribution becomes significantly more extended in the halos. Without requiring unrealistically strong feedback and outflows, the preheating model can reproduce the cold baryon mass fractions, star formation histories and the size-stellar mass relations of disk galaxies.

131 – Extrasolar Planet Characterization & Theory II

Oral Session – Maryland Ballroom A – 06 Jan 2014 02:00 pm to 03:30 pm

131.01D – Understanding Kepler's Super-Earths and Sub-Neptunes: Insights from Thermal Evolution and Photo-Evaporation

Eric Lopez[1]
1. UC Santa Cruz, Santa Cruz, CA, United States.

NASA's Kepler mission has discovered a large new population of super-Earth and sub-Neptune sized planets. Although we have no analogous planet in our own solar system, such planets are incredibly common. Understanding the nature and formation of systems of these planets is one of the key challenges for theories of planet formation. We use models of thermal evolution and photo-evaporation to constrain the structure, composition, and evolution of low-mass planets. Over time Neptune-like planets with large H/He envelopes can be transformed into rocky super-Earths. We show that differences in mass loss history provide a natural explanation for many features of the Kepler multi-planet systems, such as large density contrast between Kepler-36b and Kepler-36c. For the broader population of Kepler planets, we find that there is a threshold in bulk planet density, mass, and incident flux above which no low-mass transiting planets have been observed. We suggest that this threshold is due to XUV-driven photo-evaporation and show that it is well-reproduced by our evolution models

131.02 – Characterizing the Hot Kepler Objects of Interest

Leslie Rogers[1], Ellen Price[1], Avi Shporer[1], Justin R. Crepp[2], Jonathan Swift[1], Philip S. Muirhead[3], John A. Johnson[4]
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Planets around retired A stars (hot stars that have evolved off the main sequence) have large semimajor axes compared to planets around sun-like stars (e.g. Johnson et al. 2007, Bowler et al. 2010). This could be a side effect of the stars' evolution; increases in tidal dissipation as the stars evolve and expand may lead to the orbital decay and eventual destruction of close-in planets. Alternatively, differences in planet formation processes around these more massive stars may account for their lack of hot Jupiters. To distinguish between these two possibilities, we characterize main sequence A stars with transiting planet candidates detected by Kepler. We identify likely A stars in the Kepler Input Catalog (KIC) by their stellar effective temperatures, derived from KIC grizJHK photometry using the empirical relations from Boyajian et al. (2013). To verify the classification of a subset of these stars, we measure their spectra using Palomar DBSP and collect high-resolution images with Keck NIRC2. We determine the physical parameters of the transiting planets' orbits by fitting the Kepler transit lightcurves with Markov Chain Monte Carlo methods. By constraining the semi-major axis and eccentricity distributions of planets orbiting A stars, we gain insights into the role of stellar evolution and stellar mass in planetary systems.

131.03 – Water Clouds in Y Dwarfs and Exoplanets

Caroline Morley[1], Mark S. Marley[2], Jonathan J. Fortney[1], Roxana E. Lupu[3]
1. University of CA - Santa Cruz, Santa Cruz, CA, United States. 2. NASA Ames, Mountain View, CA, United States. 3. SETI Institute, Mountain View, CA, United States.

Clouds shape the spectra of every planet in the solar system with an atmosphere, from water clouds on Earth to ammonia clouds on Jupiter. Clouds also shape the spectra of most brown dwarf atmospheres, particularly the warmer L dwarfs, which have thick dust layers of silicate and iron clouds. Understanding the effect of clouds on the spectra of these objects is crucial if we want to characterize their compositions, surface gravities, and temperatures. Wide-field infrared surveys have pushed the detection limit of brown dwarfs to cooler and cooler objects. For brown dwarfs and planets with effective temperatures below about 450 K, the refractory iron and silicate clouds will have sunk well below the photosphere; within the photosphere, volatiles such as water will begin to condense and form clouds. The newly-proposed spectral type Y includes brown dwarfs cooler than about 500 K, many of which will have these water clouds. Over a dozen Y dwarfs have now been discovered and are beginning to be characterized; followup studies by various groups aim to measure their spectra, monitor them for variability, and measure their parallaxes. We present a grid of model atmospheres for Y dwarfs with effective temperatures from 200-450 K that include the effect of water clouds. We find that water clouds begin to form in the upper atmospheres of objects as warm as 400 K, and become optically thick in the photospheres of objects cooler than 350 K. They will most strongly influence the spectra of these objects at mid-infrared wavelengths where they absorb most efficiently, and may have some observable spectral features in the near- and mid-infrared. We present model infrared photometry and compare to Y dwarfs with measured parallaxes. We also make predictions for photometric variability in different bandpasses and spectral variability in the near-infrared. The grid of models extends to planetary gravities, allowing us to make predictions for directly-imaged planets with similar effective temperatures as they are discovered in the future.

131.04 – Synthesizing Exoplanet Demographics from Radial Velocity and Microlensing Surveys

Christian Clanton[1], B. S. Gaudi[1]
1. Department of Astronomy, The Ohio State University, Columbus, OH, United States.

Motivated by the order-of-magnitude difference in the frequency of giant planets orbiting M dwarfs independently inferred by microlensing and radial velocity (RV) surveys, we derive the mapping from the observable parameters of a planet detected by microlensing to the observable parameters of an analogous planet orbiting a RV monitored star. We use this mapping to predict the joint probability distribution of RV observables for the planet population inferred from microlensing surveys, taking care to adopt reasonable priors for, and properly marginalize over, the unknown physical parameters of microlensing detected systems. We apply our methodology to predict the number and properties of analogs of the microlensing planet population that these RV surveys should detect. We find that microlensing and RV surveys probe largely disjoint regions of parameter space, but where they overlap they are entirely consistent. We then combine the results from both surveys to provide an estimate of the frequency of planets orbiting M dwarfs with periods less than ~20 years.

131.05 – Validation by Asteroseismology for the Rocky Planet KOI 69.01

Sarah Ballard[1, 2]
1. University of Washington, Seattle, WA, United States. 2. NASA Carl Sagan Fellow, Pasadena, CA, United States.

We present a study of KOI 69.01, a 1.5 R_Earth planet around one of the brightest Kepler exoplanet host stars. The wealth of short cadence data for KOI 69 enable an asteroseismic characterization of the star, making it one of the smallest stars for which such a measurement is possible. The stellar density inferred from asteroseismology matches the density independently inferred from the exquisite Kepler transit light curve, lending credence to the planetary interpretation of the signal. The transit depth and stellar radius are determined with such precision that they render KOI 69.01 the best-measured planet outside of the solar system: its radius is known to within 120 km. A mass measurement for the planet with high-resolution radial velocity measurements confirms that the planet is almost certainty rocky in composition. The brightness of the host star KOI 69 also made it an ideal target for a new observing mode with the Spitzer Space Telescope, which gathered a wealth of 10 transits of the planet.

131.06 – Multiwavelength Photometric and Imaging observations of the Putative Disintegrating super-Mercury KIC 12557548b

Bryce Croll[1]
1. Massachusetts Institute of Technology, Cambridge, MA, United States.

I'll present multiwavelength photometric and imaging observations of the disintegrating exoplanet candidate KIC 12557548b. The intriguing Kepler photometry of this object presented by Rappaport & Collaborators, which featured variable transit depths from 1.3 to 0.2% of the stellar flux, and an occultation with a sharp ingress and gradual egress, was interpreted as evidence for light scattering from a long, comet-like tail trailing a disintegrating super-Mercury planet. I'll present HST 1.4 micron photometry and CFHT/WIRCam 2.2 micron photometric detections of the occultation of this object, that, when compared to the simultaneous Kepler optical photometry, allow us to constrain the maximum particle size of the dust tail streaming from this putative planet. I'll also present high angular resolution imaging observations of this system that allow us to rule-out false positive scenarios arising from, for instance, nearby background stars.

131.07 – A Review of Correlated Noise in Exoplanet Light Curves

Patricio Cubillos[1], Joseph Harrington[1], Matthew R. Hardin[2], Jasmina Blecic[1], Ryan A. Hardy[3]
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A number of the occultation light curves of exoplanets exhibit time-correlated residuals (a.k.a. correlated or red noise) in their model fits. The correlated noise might arise from inaccurate models or unaccounted astrophysical or telescope systematics. A correct assessment of the correlated noise is important to determine true signal-to-noise ratios of a planet's physical parameters. Yet, there are no in-depth statistical studies in the literature for some of the techniques currently used (time averaging, residual permutation, and wavelet-based likelihood fitting). We subjected these correlated-noise assessment techniques to basic tests on synthetic data sets to characterize their features and limitations. Initial results indicate, for example, that, sometimes the time-averaging method shows artifacts when the bin size is similar to the observation duration. Further, we found that the residual-permutation method doesn't correctly increase the uncertainties to compensate for the lack of accuracy if there is correlated noise. We have applied these techniques to several Spitzer secondary-eclipse hot-Jupiter light curves and discuss their implications. This work was supported in part by NASA planetary atmospheres grant NNX13AF38G and Astrophysics Data Analysis Program NNX12AI69G.

131.08 – Warm Ice Giant GJ 3470b: Revised Planetary and Stellar Parameters from Optical to Near-infrared Transit Photometry

Lauren I. Biddle[1], Kyle Pearson[1], Ian Crossfield[2], Travis S. Barman[3], Benjamin J. Fulton[4], Simona Ciceri[2], Jason Eastman[5], Andrew Howard[4], Andrew Mann[4], Gregory W. Henry[6], Michael W. Williamson[6], Evan Sinukoff[4], Diana Dragomir[5], Laura Vican[8], Adam Greenberg[8], Jake Turner[9], Robert Thompson[1], Luigi Mancini[2], Brian W. Taylor[3], Stephen Levine[3], Matthew W. Webber[7]

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We present a homogeneous analysis of new and previously published broadband photometric observations of the Uranus-sized extrasolar planet GJ 3470b. This planet belongs to the growing sample of sub-Jovian planets orbiting M dwarfs; it is important to explore the diversity of these planets' characteristics to understand the nature and evolution of this class of planets. The consistency of our analysis explains some of the discrepancies between previously published results and provides updated constraints on the planetary parameters. Our data also supports the recent evidence for a flat transmission spectrum due to a hazy or cloudy atmosphere as recently suggested for this system.

132 – Extrasolar Planet Detection - Ultra-Short-Period, Circumbinary, and Exomoons From Kepler

Oral Session – National Harbor 12 – 06 Jan 2014 02:00 pm to 03:30 pm

132.01D – A study of the shortest-period planets

Roberto Sanchis Ojeda[1], Joshua N. Winn[1], Saul A. Rappaport[1]
1. MIT, Cambridge, MA, United States.

The Kepler telescope obtained continuous high precision photometry for more than 150,000 stars for a period of 4 years. Such a unique dataset is allowing the detection of hundreds of exoplanets transiting their host stars, with orbital periods reaching up to one year and beyond. But such a dataset can also be used to discover close-in small planets, since these planets transit their host stars more frequently allowing us to combine the information from hundreds and even thousands of orbits. Here we report on a Kepler survey for the planets with the shortest possible orbital periods. We have identified a sample of 110 planet candidates with periods shorter than one day, through our own Fourier analysis of the Kepler data as well as a critical evaluation of previously reported candidates. Statistical considerations suggest that most of these candidates are true planets. One remarkable member of this population is Kepler-78b (Sanchis-Ojeda et al. 2013), an Earth-sized planet with a period of 8.5 hours, which has a host star bright enough to enable robust detections of the planetary occultations and illumination phase variations, and possibly also the radial-velocity variations induced by the planet. Another noteworthy planet is KOI 1843.03 (Rappaport et al. 2013), which is so close to its star that it must be composed mainly of iron to avoid tidal destruction. We will also present an estimate of the occurrence rate of ultra-short period planets. We find that among this population, planets smaller than 2 R_E are more common than planets between 2-3 R_E, the opposite of what has been observed among longer-period planets. This might be because gaseous atmospheres are impossible to retain under such strong irradiation. We also find that cooler stars are more likely than hot stars to host ultra-short period planets, in agreement with the previously noted trend for longer period planets. Future follow-up observations of the Kepler candidates will give a more complete picture of these extreme planetary systems.

132.02 – A Survey for Very Short-Period Planets in the Kepler Data

Brian K. Jackson[1], Christopher C. Stark[2], Elisabeth R. Adams[3], John E. Chambers[1], Drake Deming[4]
1. Carnegie DTM, Washington, DC, United States. 2. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 3. Planetary Science Institute, Tucson, AZ, United States. 4. Department of Astronomy, University of Maryland at College Park, College Park, MD, United States.

We conducted a search for very short-period transiting objects in the publicly available Kepler dataset, and our preliminary survey has revealed four planetary candidates, all with periods less than twelve hours. We have analyzed the data for these candidates using photometric models that include transit light curves, ellipsoidal variations, and secondary eclipses to constrain the candidates' radii, masses, and effective temperatures. Even with masses of only a few Earth masses, the candidates' short periods mean they may induce stellar radial velocity signals (a few m/s) detectable by currently operating facilities. The origins of such short-period planets are unclear, but we discuss the possibility that they may be the remnants of disrupted hot Jupiters. Whatever their origins, if confirmed as planets, these candidates would be among the shortest-period planets discovered so far, and such planets would be particularly amenable to discovery by the planned TESS mission.

132.03D – Discovery and characterization of circumbinary planets from Kepler

Veselin Kostov[1], Peter R. McCullough[2], Joshua A. Carter[7], Magali DELEUIL[3], Rodrigo Diaz[3], Daniel C. Fabrycky[6], Guillaume Hebrard[4], Tobias Hinse[8], Jerome A. Orosz[5], Zlatan I. Tsvetanov[1]
1. Johns Hopkins University, Baltimore, MD, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. Laboratoire d'Astrophysique de Marseille, Marseille, France. 4. L'Institut d'astrophysique de Paris, Paris, France. 5. San Diego State University, San Diego, CA, United States. 6. University of Chicago, Chicago, IL, United States. 7. Harvard University, Boston, MA, United States. 8. Korea Astronomy and Space Science Institute, Daejeon, Korea, Republic of.

Over the course of the past three years, the peerless-quality data from the NASA Kepler mission has allowed us to confirm, for the first time, the existence of eight circumbinary planets. This dissertation talk presents my contribution to the field in terms of discovery and characterization of three circumbinary planetary systems (Kepler-47, Kepler-64, KIC12351927). Here I describe the unique observational signatures of circumbinary planets, the detection method and analysis tools we developed to characterize the systems, and the theoretical implications of our discoveries. The results of my work deliver important new insight into the nature of these remarkable objects and are paramount for our understanding of a) how planets form and evolve in multiple stellar systems and b) what type of binary stars can support circumbinary planets. Adding new members to the still small family of circumbinary planets has direct relevance for estimating the planetary census in the Galaxy, and for the extension of the concept of habitability to binary stars.

132.04 – A Kepler Transiting Circumbinary Planet

William F. Welsh[1], Jerome A. Orosz[1], Daniel C. Fabrycky[2], Nader Haghighipour[3], Donald R. Short[1]
1. San Diego State University, San Diego, CA, United States. 2. University of Chicago, Chicago, IL, United States. 3. University of Hawaii, Honolulu, HI, United States.
Contributing teams: Kepler Team

Among the thousands of planet candidates discovered by Kepler only a few have been detected in binary star systems. To date, seven transiting circumbinary planets have been confirmed, with several more candidates planets under investigation. Of the confirmed cases, the planets orbit short-period eclipsing binaries that have periods between one and seven weeks. The eclipsing binary nature of the stars allows their masses and radii to be accurately determined. Perturbations of the binary can be detected by eclipsing timing variations, sometimes allowing the mass of the planet to be measured. In this talk, we present the most recent Kepler transiting circumbinary planet. We gratefully acknowledge support from the NSF via grant AST-1109928, and from NASA via Kepler PSP grant NNX12AS23G and OSS grant NNX12AI76G.

132.05 – The Hunt for Exomoons with Kepler: Results from a Survey of M-Dwarf Host Stars

David M. Kipping[1], Joel D. Hartman[2], Gaspar Bakos[2], David Nesvorny[3], Lars A. Buchhave[1]
1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 2. Princeton University, Princeton, NJ, United States. 3. Southwest Research Institute, Boulder, CO, United States.

The detection of extrasolar moons remains an outstanding observational challenge in modern astronomy and yet their existence seems probable by inspection of our own solar system. Exomoons may be detectable by searching for their transits and the gravitational influence they evoke on their host planet. With this technique, archival data from the Kepler Mission presently provides the best chance for a near-future detection. In previous works, we have shown that Kepler is sensitive to Earth-mass and radius moons for many Kepler planetary candidates with the best sensitivity occurring for low-radius M-dwarf stars, where the transit signals become enhanced. Our project, the Hunt for Exomoons with Kepler (HEK), has previously investigated nine planetary candidates orbiting G-dwarfs for evidence of exomoons, where we derived upper limits down to sub-Earth masses. In this talk, I will present the first results from a dedicated survey of Kepler planetary candidates orbiting well-characterized M-dwarfs. Not only does this survey probe to a deeper sensitivity in exomoon mass and radius, but it also investigates a spectral type where fundamentally different formation mechanisms may be in effect. I will present the results for eight planetary candidates within this class; covering the Bayesian photodynamical modeling, our final solutions for each object and briefly mention our future survey plans.

133 – Galaxy Evolution at z > 2
Oral Session – Maryland Ballroom C – 06 Jan 2014 02:00 pm to 03:30 pm

133.01 – The effect of Active Galactic Nuclei on the dust properties of high redshift Ultra Luminous Infrared Galaxies

Allison Kirkpatrick[1], Alexandra Pope[1], Anna Sajina[2], Eric Roebuck[2]
1. University of Massachusetts, Amherst, MA, United States. 2. Tufts University, Medford, MA, United States.
Contributing teams: GOODS-Herschel

The star formation rate density (SFRD) of the Universe peaks between z = 1-3, an epoch in which the SFRD is becoming increasingly dominated by Ultra Luminous Infrared Galaxies (ULIRGs). In addition to intense star formation, many ULIRGs show sign of hosting an active galactic nucleus (AGN), making them ideal for studying the concurrent buildup of stellar mass and black hole mass. We measure the effects of star formation and AGN activity in a unique sample of ~300 high redshift (z = 0.5-4.0) ULIRGs with both Spitzer mid-IR spectroscopy and deep Herschel imaging. Using the mid-IR spectra, we classify each galaxy as either dominated by star formation or AGN in the mid-IR, allowing us to identify obscured AGN that may be missed with optical or X-ray diagnostics. Based on the mid-IR classifications, we create composite spectral energy distributions (SEDs) for the AGN and star forming galaxies from the near to the far-IR/submm. Using the composite SEDs, we compare the relative strenghts of different spectral features and the relative amounts of cold and warm dust emission as a function of AGN strength and redshift. We find that the IR SEDs have similar cold dust temperatures, regardless of the mid-IR power source, but display a marked difference in the warmer dust temperatures and star formation rates due to the interplay between AGN and their host galaxy. Our publicly available empirical SEDs cover a broad range of AGN strength, redshift and luminosity, making them ideal templates to apply to other high redshift populations.

133.02 – Restframe UV colors of 1 < z < 4 star-forming galaxies in the Hubble Ultraviolet UltraDeep Field (UVUDF)

Peter Kurczynski[1], Eric J. Gawiser[1], Harry I. Teplitz[2], Marc Rafelski[2], Steven L. Finkelstein[3]
1. Rutgers, The State University of New Jersey, Piscataway, NJ, United States. 2. Infrared Processing and Analysis Center, MS 100-22, CalTech, Pasadena, CA, United States. 3. University of Texas, Austin, TX, United States.
Contributing teams: UVUDF Team

Restframe UV color is represented by the UV continuum slope, beta, which is sensitive to a galaxy's stellar age and dust reddening. We measure the correlation of beta with redshift, luminosity and stellar mass for galaxies in the range 1 < z_phot < 4, using new deep UV imaging in the Hubble Ultradeep Field. Our results probe evolution of the UV continuum across the epoch of peak star-formation in the universe and provide a context for interpreting recent studies of higher redshift star-forming galaxies.

133.03 – The Undiscovered CO: Charting the Molecular Gas of the Universe at High Redshift

Garrett K. Keating[1], Geoffrey C. Bower[1], David R. DeBoer[1], Carl E. Heiles[1], Daniel P. Marrone[2]
1. UC Berkeley, Berkeley, CA, United States. 2. University of Arizona, Tuscon, AZ, United States.

We present current results from work focused on measuring the abundance of carbon monoxide (CO) and molecular gas in the early Universe. Molecular gas is a vital component of galactic evolution and star formation; however, its distribution among average galaxies at high redshift is so poorly understood that models of the mean abundance of CO for z?2 span orders of magnitude. Direct detection methods (i.e. imaging techniques) at these redshifts have only found molecular gas in the most massive and luminous of systems ($M_{gas}=10^{10}$ M ™ ; SFR=100 M™ yr^{-1}), whereas the bulk of the molecular gas is expected to be in the unseen masses of smaller galaxies ($M_{gas}\sim10^8$ M ™; SFR~1 M™ yr^{-1}). Theory predicts these smaller galaxies are detectable as an integrated ensemble with the technique of "intensity mapping". This technique utilizes measurements of the power in different Fourier (or wave) modes in a volume of space, which are combined to construct a 3D power spectrum. The Sunyaev-Zel'dovich Array (SZA), a subset of CARMA, offers an opportunity to explore molecular gas at high redshift through intensity mapping. The SZA, an 8-element closely packed array, is capable of observing CO (J=1?0) at z=2.3-3.3. We present a power spectrum from of our current search for CO at z?3, utilizing a survey of 44 fields (20 hours integration time apiece), and a recent - and ongoing - 300 hour observation of GOODS-North, a target rich in observational data and ripe with opportunities for cross-correlation. Combined, these two datasets offer complementary perspectives (wide and shallow versus deep and narrow) to explore systematics and fidelity. We achieve a peak sensitivity of $P_N(k)=7\times10^3$ μK^2 Mpc^3, and sensitivity over length scales of k=0.5-2 h Mpc^{-1}. By comparison, theoretical models of the distribution of CO predict a signal strength of up to $P_{CO}(k)=5\times10^4$ μK^2 Mpc^3 over these length scales and redshifts.

133.04D – THE SIZE-LUMINOSITY DISTRIBUTIONS OF LYMAN-BREAK GALAXIES

Kuang-Han Huang[1, 2]
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Contributing teams: The CANDELS collaboration

Lyman-break galaxies (LBGs) comprise the largest sample of star-forming galaxies at z>3 and are crucial to our understanding of galaxy formation and evolution. Their luminosity functions allow us to calculate the cosmic star formation history, and their sizes also provide valuable information about the angular momentum content of the galaxies and dark matter halos. However, due to surface brightness dimming effects, galaxies at high redshifts are especially susceptible to selection effects; it is important to understand the selection effects before we can draw conclusions from the statistics of LBG properties. In this work we will investigate the size--luminosity distribution of LBGs between z~3 and z~6 with careful modeling of selection effects and measurement errors of size and magnitude. Our modeling is more careful than previous studies because it is performed in the two-dimensional size--magnitude space. The results of this work show that (1) the effective radii of star-forming galaxies likely evolve as H(z)^{-2/3} at a fixed luminosity, (2) the widths of the LBG size distribution are larger than expected from the spin parameter distribution of dark matter halos, and (3) the size--luminosity relation slopes of LBGs are similar to those for late-type disk galaxies in the local universe. These results favor the disk formation theory put forward by Fall & Efstathiou (1980) if the majority of LBGs are disks, but more observational evidence is needed to confirm the kinematical structure of LBGs as well as to explain the widths of the size distribution.

133.05 – Galaxies Under the Cosmic Microscope

Rachael Livermore[1]
1. University of Texas at Austin, Austin, TX, United States.

Our understanding of the average properties of distant galaxies has improved dramatically in recent years thanks to increasingly deep surveys. Yet, if we wish to understand the detailed structure of these galaxies - their morphologies and internal dynamics - pushing to high redshift is challenging. I will show how we can harness the power of gravitational lensing to magnify the images of distant galaxies that happen to lie behind clusters, enabling high-redshift (1 < z < 5) galaxies to be observed in a level of detail comparable to those at z~0.1. I will present the results of two programs to map the star formation high-redshift lensed galaxies: one with narrowband imaging from HST/WFC3 and an integral field spectroscopy program with VLT/SINFONI, Keck/OSIRIS and Gemini/NIFS. With these data, I will show that the "clumpy" morphologies observed in high-redshift star-forming galaxies are a natural consequence of the rapidly evolving gas mass fraction and dynamics of turbulent disks.

133.06 – Are All Galaxies the Same? A Synchronized, Uniform Model for Galaxy and Black Hole Evolution

Charles L. Steinhardt[1, 2], Josh S. Speagle[3, 2]

1. California Institute of Technology, Pasadena, CA, United States. 2. Kavli Institute for the Physics and Mathmatics of the Universe, Kashiwa, Chiba, Japan, Japan. 3. Harvard University, Cambridge, MA, United States.

We define a "synchronization timescale" for galaxies as a measure of the uniformity of an ensemble of galaxies at various cosmic epochs. If galaxy evolution is dominated by stochastic processes, then galactic events occurring at high redshift, such as the formation of Pop. III stars, should happen at nearly the same time across an ensemble of galaxies, while events occuring at low redshift should be much less synchronous. We measure this quantity using dozens of star formation and supermassive black hole accretion studies spanning $0 < z < 6$. Surprisingly, this synchronization timescale is both mass- and time-independent, a constant 1.2 - 1.5 Gyr for all combinations of mass and time. As a result, we propose a new framework for galactic evolution along a main sequence so that star formation, supermassive black hole accretion, and feedback between the two are dominated by deterministic rather than stochastic processes.

133.07 – BoRG: Luminosity Function and Spectroscopic Follow-Up of Galaxies at z~8

Kasper B. Schmidt[1], Michele Trenti[2], Larry D. Bradley[3], Brandon C. Kelly[1], Tommaso Treu[1], Pascal Oesch[4]

1. Physics & Astronomy, University of California Santa Barbara (UCSB), Santa Barbara, CA, United States. 2. Kavli Institute for Cosmology and Institute of Astronomy, University of Cambridge, Cambridge, United Kingdom. 3. Space Telescope Science Institute, Baltimore, MD, United States. 4. UCO/Lick Observatory, University of California, Santa Cruz, CA, United States.
Contributing teams: The BoRG Collaboration

We present the largest search to date for candidate z~8 galaxies, based on the Brightest-of-Reionizing Galaxies (BoRG) survey's 350 square arcminutes of pure parallel HST data. The search yields ~40 bright Y-band dropouts which we combine with the faint HUDF sample from Bouwens et al. (2011) to study the Luminosity function (LF) of Lyman Break Galaxies (LBGs) at z~8. We infer the parameters of the LF by developing and applying a rigorous Bayesian formalism including a likelihood function based on the correct binomial distribution. This improves on the 'standard practice' in the high redshift LF literature, where data is binned, photometric errors are not accounted for, and likelihoods are assumed to follow a poisson distribution. Our inferred credible intervals on the LF parameters include previous best-fit estimates, but the inferred uncertainties on the normalization are significantly larger than those from approximate methods. We investigate the consequences the obtained steep faint-end slope and the revised uncertainties on the normalization of the LF have on the neutral fraction of hydrogen and limits on the escape fraction and clumpiness of the IGM at z~8. We discuss this in the context of the results of our recent MOSFIRE follow-up spectroscopy of a subsample of the BoRG LBGs, which suggest that the Lyman alpha optical depth increases by at least a factor of three between z~6 and 8 (Treu, Schmidt et al. 2013).

134 – HAD V: History of Astronomy
Oral Session – National Harbor 3 – 06 Jan 2014 02:00 pm to 03:30 pm

134.01 – Astronomical Beliefs in Medieval Georgia: Innovative Approaches

Jefferson Sauter[1, 2], Wayne Orchiston[2], F. Richard Stephenson[3]
1. University of Southern Queensland, Toowoomba, QLD, Australia. 2. National Astronomical Research Institute of Thailand, Chiang Mai, Thailand. 3. University of Durham, Durham, United Kingdom.

Written sources from medieval Georgia show, among other things, how astronomical ideas were adapted on the periphery of the Byzantine and Islamic worlds. In this paper, we investigate a number of Georgian beliefs about the heavens from a calendrical work and a celestial prognostication text, but also from less expected sources including the medieval life of a saint and an epic poem. For the most part, these sources were derived from Byzantine or Persian models. We show the extent to which the sources nevertheless conform to a specifically Georgian view of the cosmos. We argue that, in so doing, medieval Georgian authors employed several innovative approaches hitherto unnoticed by modern scholars.

134.02 – Habitability and the Possibility of Extraterrestrial Life in the Early Telescope Era

Sarah Reynolds[1]
1. Indiana University, Bloomington, IN, United States.

Early telescopic observations of the Moon and planets prompted great interest in the already-existing debate about the possibility of life on the Moon and other worlds. New observations of the lunar surface, revealing an apparently Earth-like terrain and possibly the presence of bodies of water, were often considered in relation to their implications for the existence of lunar inhabitants. This depended upon establishing what constituted the fundamental requirements for life and the boundaries of habitability. The growing support for the heliocentric Copernican astronomy was also changing perceptions of the relationships between the Earth, the Moon, and the planets. Works such as Johannes Kepler's *Somnium* and John Wilkins' *The Discovery of a World in the Moone* presented views of extraterrestrial life that were shifting from the supernatural to the natural, in correspondence with the celestial bodies' new positions in the cosmos. This paper considers how these and other works from the early telescope era reveal changes in the nature of astronomical speculation about extraterrestrial life and the conditions construed as "habitability," and what significance that history has for us today in the new era of extrasolar planet discovery.

134.03 – What exactly was William Herschel's Milky Way and how did he construct it?

Woodruff T. Sullivan[1], Ramon Sharma[1]
1. Univ. of Washington, Seattle, WA, United States.

William Herschel is famous for his "Construction of the Heavens," his pioneering quantitative view of the Milky Way based on extensive star counts ("gages") carried out while sweeping with his 20-ft telescope in the early 1780s. In 1785 he presented his main result in a single iconic diagram - a view of the Milky Way that was to dominate for over a century until "Kapteyn's Universe" finally overtook it in the early 20th century. In this paper we analyze the entire data sample of Herschel's published and unpublished star gages in order better to understand the nature of the data and how he used them. We examine such issues as his method of observing, his limiting magnitude, his consistency in star counting, his sky coverage, and his distance scaling (in units of "visual rays"). We also discuss how representative was his lone published 2-D slice through his model Milky Way, and the effects of his basic assumptions (such as a uniform density of stars). Where insight can be gained, we make comparisons with modern star counts (such as those of the HST Guide Star Catalog). To assist in this effort we have employed 3-D visualization software, as well as a plastic model (to be exhibited) constructed by a 3-D printer illustrating many aspects of the Herschelian Milky Way.

134.04 – An Enigmatic Portrait

Thomas A. Hockey[1]
1. University of Northern Iowa, Cedar Falls, IA, United States.

One of the up-scale commercial auction houses presented me with a gift. It is a 23 cm wide X 29 cm tall plaque upon which is mounted a smaller bronze plaque in relief. The figure on that bronze is a profile from the left of Eleanor Annie Lamson (1875-1932), who became the first female supervisor at the United States Naval Observatory [USNO] , in its Washington, D. C., Computing Bureau. That the artwork is Lamson is attested to by the " Annie Lamson" in relief letters above her head. Comparing the plaque to photographs of Lamson shows that it is a fair likeness. What is not so clear is the provenance of this artifact and the reason for which it was cast. Thanks to Steve Dick and other sources, I know that Annie Lamson obtained her

Bachelor of Science degree in 1897 and Master of Science degree in 1899 from George Washington University. She joined the Observatory as a Miscellaneous Computer in 1900. By 1903 she was a full-time computer and by 1907 an assistant in the Computing Division. She served as Head of the Computing Bureau from 1921 until her death at age 57. More biographical information and photographs are available at http://maia.usno.navy.mil/women_history but nothing that illuminates our find. The plaque apparently was created in 1920, at which time Lamson had been with the USNO for twenty years. The artist is George Raab (1866-1943) of Wisconsin, but who was well traveled. That is about all we know. The plaque will be on display during the time allotted for my presentation. Why was the plaque commissioned? What is its history? Was it once a part of a set? At this time I will call upon the collective wisdom to help solve the mystery.

134.05 – Simon Newcomb, Other Aspects of His Career

Brenda G. Corbin[1]
1. U. S. Naval Observatory (retired), Washington, DC, United States.

Simon Newcomb (1835-1909) is perhaps the best known American astronomer of the late 19th century. Among the many aspects of his long career, he was one of the founders and the first president of what later became the American Astronomical Society. However, he wrote widely on subjects other than astronomy, even producing works of fiction. He was especially interested in economics and published such titles as *A critical examination of our financial policy during the Southern rebellion*, *A plain man's talk on the labor question*, *Principles of political economy* and others. The very interesting title, *A statistical inquiry into the probability of causes of the production of sex in human offspring* was written in 1904. Newcomb even produced a work of science fiction, *His Wisdom, the Defender: a story*, published in 1900. William Alvord, President of the Astronomical Society of the Pacific, on awarding Newcomb the Bruce Medal stated "The essential quality of his mind is that of a philosopher rather than that of a mathematician or an astronomer merely." It has been suggested (Bradley Schaefer and others) that Arthur Conan Doyle used Newcomb as the model for Prof. Moriarty in his Sherlock Holmes novels. He had close friendships with many scientists of his time including Alexander Graham Bell. On the other hand, it has been reported that he also had contentious relationships with some scientists and could be intimidating. A devoted family man, he encouraged his three daughters in their intellectual pursuits. Newcomb, who held naval rank in the Corps of Professors of Mathematics, was buried in Arlington National Cemetery with full military honors. His funeral was attended by many noted scientists and other dignitaries including President William Howard Taft.

134.06 – Celebrating 130 Years of the Alvan Clark Telescope at Albion College

Nicolle Zellner[1], *Nicole Garrett Smeltekop*[1]
1. Albion College, Albion, MI, United States.

This year, 2013-2014, marks the 130th anniversary of the 8" Alvan Clark refracting telescope and observatory building at Albion College, an undergraduate college in Albion, MI. Completed in 1884, the observatory is an excellent example of a nineteenth century astronomical building; its telescope is still useable and other instruments (Fauth and Company sidereal clock, transit telescope, and chronograph) are in very good condition. The building has a long history, serving once as a barracks for World War I soldiers, and the telescope has helped to train the next generation of scientists, from Forest Ray Moulton (Class of 1894) to present-day students. Several times each year, the telescope is open to the public and to the campus community for public observing events, and during the anniversary year, several other activities are planned. I will describe the history of our observatory and its people and give an overview of the events planned for this year.

134.07 – Lemaître's Limit(s) to our Universe(s)

Ian Steer[1]
1. NED, Toronto, ON, Canada.

Georges Lemaître gave a theoretical proof for his 1927 doctoral thesis in astronomy that the maximum spherical radius of our Universe can be computed from first principles to be 14.2 billion light-years. That estimate, which is known as Lemaître's limit, is within 3% of current estimates of the Universes age. Further, the most precise estimate of the Hubble constant to date, $H = 69.3$ km/s/Mpc from the full nine-years of Wilkinson Microwave Anisotropy Probe measurements, is within 1% of the value predicted based on Lemaître's Limit, $H = 68.7$ km/s/Mpc. If Lemaître's Limit is resurrected, it will revolutionize cosmology.

135 – HEAD II: Consistent Cluster Cosmology: What are Planck, SZ telescopes, and X-ray observations telling us?

Special Session – National Harbor 5 – 06 Jan 2014 02:00 pm to 03:30 pm

The recent flood of results from Planck, ACT and SPT combined with over a decade of work with Chandra, XMM-Newton, and other X-ray satellites have provided a wealth of cluster survey data. While largely consistent, there are discrepancies that could be calibration issues but might also be pointing the way to new discoveries. This session will feature talks by leaders in each area, followed by a moderated debate discussing both the possible solutions to these inconsistencies and what the future might bring.

135.01 – Planck Cluster Cosmology Results

James G. Bartlett[1]

1. Jet Propulsion Laboratory and APC Univ. Paris 7, Pasadena, CA, United States.

Contributing teams: Planck Collaboration

We will present the cluster cosmology results from Planck. The cluster constraints show significant tension with constraints from the primary cosmic microwave background analysis from Planck, assuming a standard LCDM model. This tension is also supported by our measurements of the diffuse SZ power spectrum. I will discuss the origin of this tension, and possible explanations and their potentially important implications for cosmology and galaxy cluster science.

135.02 – The South Pole Telescope Cluster Survey

Bradford Benson[2, 1]

1. Enrico Fermi Institute, Chicago, IL, United States. 2. University of Chicago, Chicago, IL, United States.

Contributing teams: The SPT, SPTpol, and SPT-3G Collaborations

The South Pole Telescope (SPT) is a 10-meter diameter mm-wavelength telescope optimized for low-noise measurements of the cosmic microwave background (CMB). The SPT experiment consists of three completed, underway, or planned surveys: 1) SPT-SZ (2007-2011), 2) SPTpol (2012-2015), and 3) SPT-3G (2016-2019). I will describe all three, focusing on their respective Sunyaev-Zel'dovich (SZ) cluster surveys. The SPT-SZ survey has provided a new catalog of approximately 500 of the most massive, distant clusters in the universe, about 75% of which are new discoveries. I will describe the catalog and the resultant cosmological constraints, including how multi-wavelength follow-up is used to improve the accuracy of the cluster mass calibration; primarily from X-ray observations with Chandra and XMM, and weak lensing observations with the Magellan and Hubble telescopes. I will also preview early results from the SPTpol survey, including the first detection of B-modes in the polarization of the CMB and the SPTpol cluster survey, which we expect to detect nearly a factor of two more clusters than SPT-SZ. The next-generation SPT-3G survey should find yet another order of magnitude more clusters, and detect CMB cluster lensing with better accuracy than current uncertainties in the cluster mass calibration.

135.03 – X-ray Cluster Cosmology from Einstein to eROSITA

Christine Jones[1]

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.

Contributions from X-ray observations of clusters of galaxies to cosmological studies include 1) constraints on cosmological parameters derived from comparing the mass functions of clusters or baryon fractions as a function of redshift, which constrain Omega_matter, sigma_8, and the Dark Energy equation of state, 2) constraints on the mass of light neutrinos and the self-interaction cross-section of dark matter, 3) tests of modified gravity models, and 4) improved understanding of the formation and growth of clusters and supermassive black holes over cosmological time, including the formation of cooling cores, AGN feedback and heavy element enrichment of the intracluster medium. This talk will focus on the results of cluster surveys from the current X-ray missions Chandra and XMM-Newton, past missions Einstein and ROSAT, and those expected from the future eROSITA all-sky survey.

136 – Instrumentation II: Ground Missions
Oral Session – Maryland 2 – 06 Jan 2014 02:00 pm to 03:30 pm

136.01D – Heterodyne Arrays for Terahertz/Sub-millimeter Astronomy

Jenna Kloosterman[1], Christopher K. Walker[1]
1. University of Arizona, Tucson, AZ, United States.
Contributing teams: SORAL, SRON, TU-Delft, JPL, APL, ASU, MIT

The clouds of gas and dust that constitute the Interstellar Medium (ISM) within the Milky Way and other galaxies can be studied through the emission from atoms and molecules such as CO, [CI], [CII], [NII], and [OI]. Spectroscopic surveys of these tracers are necessary to disentangle large-scale structure and kinematics within the ISM. Each of these tracers has transitions in the Terahertz (THz) region of the electromagnetic spectrum, loosely defined as 0.3 – 3 THz, thus creating a need for large format THz heterodyne arrays. My dissertation research in radio instrumentation has focused on three main projects. The first, the Superheterodyne Camera (SuperCam), is a ground-based instrument for the Sub-millimeter Telescope (SMT) on Mt. Graham, Arizona. The receiver contains 64 heterodyne pixels designed to detect the J=3-2 rotational line of CO at 345 GHz. SuperCam had its first engineering run in Spring 2012 and its commissioning run in Spring 2013. The second project, the Stratospheric Terahertz Observatory (STO), is a balloon-borne, 0.8 m telescope, designed to observe the fine structure lines of [NII] and [CII] at 1.46 and 1.9 THz from an altitude of ~120,000 ft. STO had its first flight around Antarctica in January 2012 and is scheduled to have a second flight (as STO-2) in 2015. The last project is the building of a 4.74 THz heterodyne receiver to look for the fine structure line of the high density tracer [OI]. With an 815 K double sideband noise temperature (e.g. ~7 times the quantum noise limit), this is the most sensitive heterodyne receiver reported above 3 THz. It will be flown on STO-2 and was developed as part of the Galactic/extra-galactic Ultra-Long Duration Stratospheric Spectroscopic THz Observatory (GUSSTO) concept study. This dissertation talk will briefly cover the results of these instrumentation efforts and the science that drives them.

136.02 – Prototype Development of the GMT Fast Steering Mirror

Young-Soo Kim[1], Ju Heon Koh[1], Hwa Kyoung Jung[1], Ho June Jung[1], Myung K. Cho[2], Won Hyun Park[3], Ho-Soon Yang[4], Ho-Sang Kim[5], Kyoung-Don Lee[5], Hyo-Sung Ahn[6], Byeong-Gon Park[1]
1. KASI, Daejeon, . 2. NOAO, Tucson, AZ, United States. 3. The University of Arizona, Tucson, AZ, United States. 4. KRISS, Daejeon, Korea, Republic of. 5. IAE, Yongin, Korea, Republic of. 6. GIST, Gwangju, Korea, Republic of.

A Fast Steering Mirror (FSM) is going to be provided as the secondary of the Giant Magellan Telescope (GMT) for the first light observations. FSM is 3.2 m in diameter and the focal ratio is 0.65. It is composed of seven circular segments which match with the primary mirror segments. Each segment contains a light-weighted mirror whose diameter is 1.1 m, and each mirror is activated by three tip-tilt actuators which compensate image degradations caused by winds and structure jitter. An FSM prototype (FSMP) has been developed to achieve the key technologies, fabrication of highly aspheric off-axis mirror and precise tip-tilt actuation. It consists of a full-size off-axis mirror segment and a tip-tilt test-bed. The development has been conducted by Korea Astronomy and Space Science Institute together with four other institutions in Korea and USA. The mirror was light-weighted by digging about a hundred holes at the backside, and the front surface has been polished. The result of computer generated hologram measurements showed the surface error of 11.7 nm rms. The tip-tilt test-bed has been manufactured and assembled. Tip-tilt range and resolution tests complied the requirements, and the attenuation test results also satisfied the performance requirements. In this paper, we present the successful developments of the prototype.

136.03 – Astrophysical Observations with the HEROES Balloon-borne Payload

Colleen Wilson[1], Jessica Gaskin[1], Steven Christe[2], Albert Y. Shih[2], Douglas A. Swartz[3], Allyn F. Tennant[1], Brian Ramsey[1]
1. NASA's MSFC, Huntsville, AL, United States. 2. NASA's GSFC, Greenbelt, MD, United States. 3. USRA/MSFC, Huntsville, AL, United States.

The High Energy Replicated Optics to Explore the Sun (HEROES) payload flew on a balloon from Ft. Sumner, NM, September 21-22, 2013. HEROES is sensitive from about 20-75 keV and comprises 8 optics modules, each consisting of 13-14 nickel replicated optics shells and 8 Xenon-filled position-sensitive proportional counter detectors. HEROES is unique in that it is the first hard X-ray telescope that will observe the Sun and astrophysical targets in the same balloon flight. Our astrophysics targets include the Crab nebula and pulsar and the black hole binary GRS 1915+105. In this presentation, I will describe the HEROES mission, the data analysis pipeline and calibrations, and preliminary astrophysics results.

136.04D – FIREBall, CHAS, and dusty Galactic Clouds

Erika T. Hamden[1], David Schiminovich[1], Sam Gordon[1]
1. Columbia University, New York, NY, United States.

This work integrates observing and instrumentation projects to explore diffuse gas and dust in the interstellar and circumgalactic medium (ISM, CGM). We first present an all sky map of the diffuse Galactic FUV background using all sky survey data from GALEX. We focus in detail on the FUV behavior of selected dusty Galactic clouds and their relationship to 100 micron emission. We also describe ongoing instrumentation projects aimed at observing the CGM around galaxies at a range of redshifts. The Faint Intergalactic Redshifted Emission Balloon (FIREBall), is a balloon borne multi-object spectrograph designed to observe the CGM using ultraviolet emission lines (Lyman alpha, CIV, OVI) redshifted into an atmospheric window at 205nm. FIREBall will also serve as a test-bed for a high efficiency CCD UV detector, which has achieved world record quantum efficiency at these wavelengths. We present both the detector technology and predicted detection limits in anticipation of a launch in 2015. The Circumgalactic H-alpha Spectrograph (CHAS), is a narrowband H alpha IFU designed to detect the CGM in nearby galaxies. We present recent data from a successful prototype built entirely at Columbia (proto-CHAS), along with anticipated detection limits for long duration observations.

136.05 – NRES: The Network of Robotic Echelle Spectrographs

Jason Eastman[1, 2], Timothy M. Brown[3, 1], John Hygelund[1], Julian C. Van Eyken[2, 1]
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Las Cumbres Observatory Global Network (LCOGT) is building the Network of Robotic Echelle Spectrographs (NRES), which will consist of six identical, optical (390 - 860 nm) high-precision spectrographs, each fiber-fed simultaneously by two 1 meter telescopes and a thorium argon calibration source, one at each of our observatory sites in the Northern and Southern hemispheres. Thus, NRES will be a single, globally-distributed, autonomous observing facility using twelve 1-m telescopes. Simulations suggest we will achieve long-term precision of better than 3 m/s in less than an hour for stars brighter than V = 12. We have been fully funded with an NSF MRI grant, and expect our first spectrograph to be deployed in Spring of 2015, with the full network operation of all 6 units beginning in Spring of 2015. We will discuss the NRES design, goals, and robotic operation, as well as the early results from our prototype spectrograph.

136.06 – Improvements to the Flux Density Scale between 220 and 460 MHz

Richard A. Perley[1], Huib Intema[1], Minnie Mao[1], Anna Scaife[2]
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Two recent publications have proposed new polynomial expressions to describe the flux density scale at radio wavelengths. Perley and Butler (2013), using the absolute flux density of Mars, have provided expressions for four non-varying standard sources valid from 1 to 50 GHz. Scaife and Heald (2012), by reanalyzing observations taken between 1968 and 1997, have provided best-fit expressions, valid between 50 and 1000 MHz, for six strong and compact objects. Neither scale is based on an absolute reference for frequencies below 1000 MHz. The VLA has recently completed installation of a new receiver system, spanning the frequency range from 50 to 500 MHz. Observations of the standard calibrators from both the Perley and Butler, and Scaife and Heald papers have been made, along with observations of the powerful sources Taurus A, Virgo A, and Cygnus A, for which absolute flux densities are known. From these, we produce an absolute scale for the standard calibrators, valid between 220 and 460 MHz.

137 – Intergalactic Medium & QSO II
Oral Session – Potomac Ballroom C – 06 Jan 2014 02:00 pm to 03:30 pm

137.01 – The Rapid Evolution of HI Rich Galaxies at z~5

Marc Rafelski[1], Marcel Neeleman[2], Arthur M. Wolfe[2], Jason X. Prochaska[3], Michele Fumagalli[4, 5]
1. IPAC / Caltech, Pasadena, CA, United States. 2. UCSD, La Jolla, CA, United States. 3. UCSC, Santa Cruz, CA, United States. 4. Carnegie Observatories, Pasadena, CA, United States. 5. Princeton University, Princeton, CA, United States.

Measurements of the chemical evolution of damped Ly-alpha systems (DLAs) show a linear decrease in the metallicity of DLAs with increasing redshift out to z~4.7. We present evidence for a sudden decrease or break in the chemical abundances of damped Ly-alpha systems (DLAs) at z~5, doubling the previous sample size at this redshift. This break may represent a transition in the nature of DLAs above z~4.7. Specifically, the lower UV radiation field and higher density at high redshift increases the neutral fraction of gas inside halos, such as the lower metallicity cold streams, thereby contributing more significantly to the DLA population. This would result in more low metallicity systems being classified as DLAs. Even with the observed break, we show that the metallicity 'floor' of ~1/600 solar continues out to z~5, despite our sensitivity for finding DLAs with much lower metallicities. In addition, we find preliminary evidence suggesting that the the comoving HI mass density and the incidence of DLAs at z~5 may be decreasing or flattening out, even though they are predicted to increase, due to an increase in the neutrality of cold accreting gas as we approach the epoch of reionization.

137.02 – The large-scale distribution of gas

Guangtun Zhu[1], Brice Ménard[1, 2], Dmitry Bizyaev[3], Shirley Ho[4], Surhud More[2]
1. Johns Hopkins University, Baltimore, MD, United States. 2. Kavli IPMU (WPI), the University of Tokyo, Kashiwa, Japan. 3. Apache Point Observatory and New Mexico State University, Sunspot, NM, United States. 4. Carnegie Mellon University, Pittsburgh, PA, United States.

The circumgalactic medium contains signatures of key processes in galaxy formation such as gas accretion and outflow and may account for the majority of baryons in the Universe. To probe gas in this environment, we measure the mean absorption induced by galaxy halos using all available quasar-galaxy pairs in the SDSS (of the order of several million). This method does not require the detection of individual absorber systems but is able to extract weak absorption signals below the noise of individual spectra. As a result, we can measure the radial distribution of gas with an unprecedented sensitivity, reaching rest equivalent width of 0.0001 Angstrom. We are able to measure Ca II absorption up to 200 kpc around galaxies and Mg II up to 20 Mpc. We also extract relationships between galaxy properties (stellar mass, SFR, orientation) and the amount of gas in their halos. On the large scale, the measured galaxy-gas correlation function reveals a clear transition from the 1-halo to 2-halo regime which we study quantitatively with a new dark matter-gas halo model. We also measure the velocity dispersion of cool gas clouds in the halo and interpret it in the cosmological context. I will further discuss the new constraints these results bring to the physics of gaseous halos.

137.03D – Glimpsing Host Galaxies of High-Redshift Quasars Using Strong Damped Lyman-Alpha Systems as Coronagraphs

Hayley L. Finley[1], Patrick Petitjean[1], Isabelle Paris[2], Pasquier Noterdaeme[1]
1. Pierre and Marie Curie University (Paris 6), Paris, France. 2. Universidad de Chile, Santiago, Chile.
Contributing teams: SDSS III - BOSS

Active Galactic Nuclei (AGN) play a crucial role in galaxy evolution because they provide radiative and mechanical feedback to their host galaxies and the intergalactic medium. Spectroscopic observations reveal the effects of AGN on their host galaxies at the z = 2 - 3 epoch, when the quasar luminosity function peaks. We searched quasar spectra from the SDSS-III Baryon Oscillation Spectroscopic Survey (BOSS) for rare occurrences where a strong damped Lyman-alpha absorption system (DLA) occurs at the redshift of the observed quasar. These DLAs act as natural coronagraphs to block the Broad Line Region emission from the quasar and reveal narrow Lyα emission from the host galaxy. Such systems offer a unique probe of the quasar host galaxy. The DLA provides a measure of the gas composition in the galactic environment, while the narrow Lyα emission can be linked to ionization. We define a statistical sample of 31 DLAs in Data Release 9 (DR9) with log N(HI) ? 21.3 cm^{-2} located at less than 1500 km s^{-1} from the quasar redshift. In 25% (8) of these DLAs, a strong narrow Lyα emission line is observed with average flux ~25×10^{-17} erg s^{-1} cm^{-2}. Analyzing the statistical sample, we do not find substantial differences in the kinematics, metals, or reddening for the two populations with and without emission detected. To better characterize properties of the host galaxy emission, we examine a sample of 26 DLAs from DR9 and DR10 with narrow Lyα emission detected and no limit on the HI column density. The highly symmetric narrow Lyα emission line profile centered in the HI trough indicates that the emitting region is separate from the absorber. The luminosity of the narrow Lyα emission peaks is intermediate between that of Lyman-alpha emitters and radio galaxies, implying that the Lyα emission is

predominantly due to ionizing radiation from the AGN. Galaxies neighboring the quasar host are likely responsible for the majority (>75%) of these DLAs, although a minority (<25%) may arise from HI clouds located in the AGN host galaxy.

137.04 – Proposal for Definitive Survey for Fast Radio Bursts at the Allen Telescope Array

Gerald Harp[1,2], Jill C. Tarter[1,2], William J. Welch[2]
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Contributing teams: Allen Telescope Array Team

The Allen Telescope Array, a 42-dish radio interferometer in Northern California is now being upgraded with new, more sensitive receivers covering 0.9-18 GHz continuously. Leveraging this frequency coverage and wide field of view, the ATA is a unique and ideal instrument for the discovery and characterization of fast radio bursts (FRBs, discovered at Parkes and Arecibo) and other short-time domain radio phenomena. The field of view (nearly 10 sq. deg. at 1 GHz) allows for a rapid search of 3? steradians with many lookbacks over a period of 2.5 years. The instantaneous wide-frequency range of the upgraded ATA receivers allows sensitive observations at 4 simultaneous frequency ranges (for example, 0.9 - 1.5 GHz, 1.6-2.2 GHz, 2.5-3.1 GHz, and 4.6-5.2 GHz, full Stokes); something not possible at any other major telescope. This enables very accurate dispersion measure and spectral index characterization of ms-timescale bursts (or other time-variable activity) with a localization accuracy ~20" for SNR > 10 (all FRBs discovered to date would meet this criterium). We discuss the new digital processing system required to perform this survey, with a plan to capture ~400 FRB events during the survey period of performance , based on current event-rate estimates of 10^4 events/sky/day.

137.05 – Variation of Fundamental Constants: the Impact of Wavelength Miscalibrations

Jonathan B. Whitmore[1]
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The metal absorption lines found in high resolution QSO spectra have been at the forefront of measurements of several fundamental dimensionless constants of nature. These measurements are made by comparing the relative wavelength spacings of absorption lines found of QSO spectra. The fine-structure constant (alpha) and the mass ratio of the proton to electron (mu) are two fundamental constants that have been measured to a precision of a few parts per million in the redshift range ~0.5--4.0. They thus require detailed wavelength calibration. The high resolution telescope/spectrograph pairs of the VLT-UVES and Keck-HIRES have provided the measurements resulting in evidence of a change in the value of alpha over cosmological time. Measurements of alpha in hundreds of absorption systems in a study combining data from both spectrographs have lead to a proposed spatial dipole across the sky. In recent months, several long-range wavelength calibration distortions have been found with direct implications for alpha and mu measurements taken with each spectrograph. The effects on the previously published results will be presented.

137.06 – The Covering Factor of the Dense Circumgalactic Medium in the COSMOS Field at z < 1

Joseph Ribaudo[1], Nicolas Lehner[2], J. C. Howk[2]
1. Utica College, Utica, NY, United States. 2. University of Notre Dame, Notre Dame, IN, United States.

Understanding the origins and physical distribution of the extended gaseous environments of galaxies, known as the circumgalactic medium (CGM), is critical in determining how the circulation of gas impacts the formation and evolution of galactic structures over cosmic time. To investigate the distribution of dense gas around galaxies we estimate the covering factor of the CGM of galaxies probed by H I absorbers with ? > 2 at the Lyman limit (a.k.a., optically-thick absorbers) in the COSMOS field. Using UV spectroscopy of 27 QSOs observed with GALEX, combined with deep HST imaging and ground based observations of the galaxies in the QSO fields, we find the covering factor of the optically-thick CGM is less than unity at small impact parameters (< 25 kpc) and drops considerably to < 10% at 200 kpc. The sample of galaxies within the COSMOS field that do not give rise to an optically-thick absorption signature also place significant constraints on the composition and distribution of the CGM at z < 1.

137.07 – Spatially Resolved Emission of a High Redshift DLA Galaxy with the Keck/OSIRIS IFU

Regina Jorgenson[1], Arthur M. Wolfe[2]
1. Institute for Astronomy, University of Hawaii, Honolulu, HI, United States. 2. University of California, San Diego, San Diego, CA, United States.

We present the first Keck/OSIRIS infrared IFU observations of a high redshift damped Lyman α (DLA) galaxy detected in the line of sight to a background quasar. By utilizing the the Laser Guide Star Adaptive Optics (LGSAO) to reduce the quasar PSF to FWHM ~ 0.15 arcsec, we were able to search for and map the foreground DLA emission free from the quasar contamination. We present maps of the Hα and [OIII] emission of DLA2222-0946 at a redshift of z=2.35. From the composite spectrum over the Hα emission region we measure a star formation rate of ~9.5 solar masses per year and a dynamical mass of $M_{dyn} = 6.1 \times 10^9$ solar masses. The average star formation rate surface density is 0.55 solar masses yr^{-1} kpc^{-2}, with a central peak of 1.7 solar masses yr^{-1} kpc^{-2}. Using the standard Kennicutt-Schmidt relation, this corresponds to a gas mass density of 243 solar masses pc^{-2}. Integrating over the size of the galaxy we find a total gas mass of $M_{gas} = 4.2 \times 10^9$ solar masses. We estimate the gas fraction of DLA2222-0946 to be f_{gas} ~40%. We detect [NII] emission at 2.5? significance with a flux corresponding to an oxygen metallicity of 75% of solar. Comparing this with the metallicity derived from the low-ion absorption gas, ~30% solar, at ~6 kpc away we see possible evidence for a metallicity gradient or enriched in/outflow of gas. Kinematically, both Hα and [OIII] emission show relatively flat velocity fields over the central galactic region. While we detect some red and blueshifted clumps of emission, they do not correspond with rotational signatures that would support an edge-on disk interpretation.

138 – Interstellar Medium & Dust II
Oral Session – Maryland 1 – 06 Jan 2014 02:00 pm to 03:30 pm

138.01D – SPINR Sounding Rocket Measurements of Far-Ultraviolet Dust Scattering Properties in Orion

Christopher Mendillo[1], Timothy Cook[1], Supriya Chakrabarti[1], Karl D. Gordon[2]
1. UMASS Lowell, Lowell, MA, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States.

Wide-field observations of the Orion OB stellar association were performed in the far-ultraviolet using the Spectrograph for Photometric Imaging with Numeric Reconstruction (SPINR) sounding rocket. These observations reveal the diffuse signature of starlight scattering off interstellar dust grains. The spectral-imaging data were used along with a three-dimensional radiative transfer model to measure the dust scattering parameters: the grain albedo (a) and the scattering asymmetry (g). The measured parameters are consistent with previous measurements made toward Orion. A sharp increase in albedo was measured at ~1330 Å. This feature is not explained by current grain models. The constructed three-dimensional model of Orion includes a two-component dust distribution. The foreground distribution is responsible for the small amount of visible reddening measured toward the bright stars in the Orion constellation. The background distribution represents the Orion Molecular Cloud, which dominates observations of dust emission in the infrared. This model was used to show that backscattered light from the molecular cloud alone cannot produce the observed scattered light distribution. The foreground dust, though optically thin in the visible, significantly contributes to the scattered light in the far-ultraviolet. This suggests that observations of Orion in the infrared and far-ultraviolet may probe entirely different dust populations.

138.02 – [CI] and CO in local galaxies from the Beyond the Peak Project

Alison F. Crocker[1], Eric W. Pellegrini[1], John-David T. Smith[1]
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Contributing teams: Beyond The Peak Team

From simple plane-parallel photodissociation region (PDR) models, neutral carbon ([CI]) is predicted to exist in a thin layer between C+ and CO on the surface of molecular clouds (e.g. (Hollenbach & Tielens 1999, Kaufman et al. 1999). However, observations of the Milky Way and the Magellanic Clouds indicate that [CI] may instead be a better tracer of the entire cold gas reservoir, often very well correlated with emission from ^{12}CO(1-0) or ^{13}CO(1-0) (e.g. Keene et al. 1996, Bolatto et al. 2000, Shimajiri et al. 2013). Here, we present the observed [CI] fluxes from the Beyond the Peak sample of 22 nearby galaxies observed with the Herschel FTS spectrometer. We first attempt to model all CO transitions and the [CI] lines as a single plane-parallel PDR, but this fails in all cases. Instead, a two-component PDR model is able to fit the CO SLED of nearly all galaxies. We investigate correlations of the [CI] fluxes and line ratio with properties of the cooler component determined from the PDR fits.

138.03 – Estimating PAH Contribution To YSO Spectra Via IR And UV Band Strengths Of Pyrene Frozen In Water Ice

Emily E. Hardegree-Ullman[1], Abraham C. Boogert[2], Murthy Gudipati[3], Hanna Lignell[4]
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Infrared emission features at ~3.3, 6.2, 7.7, 8.6, and 11.3 microns have long been attributed to polycyclic aromatic hydrocarbons (PAHs) in the gas phase interstellar medium (ISM). These PAHs are thought to account for a significant (10-20%) portion of the carbon reservoir in the Milky Way and as such could be of great astrobiological importance. While PAH emission has not been detected toward embedded young stellar objects (YSOs), tentative detections in absorption at ~3.25 microns have been reported (e.g. Sellgren et al. 1994; Brooke et al. 1996, 1999). Taken in context with the strong ice absorption present, any PAHs in these systems are likely frozen onto the icy mantles of dust grains. This work reexamines YSO spectra (Boogert et al. 2008) to estimate the contribution of frozen PAHs to unidentified absorption in the 5-8 micron spectral region. To do so, laboratory experiments were conducted to determine the band positions, widths, and strengths of pyrene features when frozen in H2O and D2O ices. These results were compared with previous experiments (Bouwman et al. 2011), and the PAH abundances toward YSOs were constrained based on the observations and laboratory data. This work was supported by an IPAC Visiting Graduate Fellowship.

138.04 – Towards a Full-sky, High-resolution Dust Extinction Map with WISE and Planck

Aaron M. Meisner[1, 2], Douglas P. Finkbeiner[1, 2]

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We have recently completed a custom processing of the entire WISE 12 micron All-sky imaging data set. The result is a full-sky map of diffuse, mid-infrared Galactic dust emission with angular resolution of 15 arcseconds, and with contaminating artifacts such as compact sources removed. At the same time, the 2013 Planck HFI maps represent a complementary data set in the far-infrared, with zero-point relatively immune to zodiacal contamination and angular resolution superior to previous full-sky data sets at similar frequencies. Taken together, these WISE and Planck data products present an opportunity to improve upon the SFD (1998) dust extinction map, by virtue of enhanced angular resolution and potentially better-controlled systematics on large scales. We describe our continuing efforts to construct and test high-resolution dust extinction and temperature maps based on our custom WISE processing and Planck HFI data.

138.05D – Are far-IR fluxes good measures of cloud mass?

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1. Physics and Astronomy, University of Kentucky, Lexington, KY, United States. 2. University of Cincinnati: Clermont College, Batavia, OH, United States.

It is commonly assumed that the Herschel far-IR fluxes are a measure of column density, hence, mass of interstellar clouds. The Polaris Flare, a high galactic latitude cirrus cloud, with several starless molecular cores, has been previously observed with the Herschel Space Telescope. We used Cloudy version 13.02 to model a molecular cloud MCLD 123.5+24.9, one of the denser regions of the Polaris Flare. These models include a detailed calculation of far-IR grain opacities, subject to various assumptions about grain composition, and predict far-IR fluxes. The models suggest that the observed fluxes reflect the incident stellar UV radiation field rather than the column density, if N(H) > a few times 10^{21} cm^2 (A$_V$ > 1). For higher column densities, the models show that dust temperatures decline rapidly into the cloud. Therefore, the cloud interiors contribute very little additional far-IR flux, and column densities based upon far-IR fluxes can be significantly underestimated. The Polaris Flare, 150 pc distant, is well within the Galactic disc. There are no nearby hot stars. Therefore, the stellar UV radiation field incident on the cloud should be close to the mean interstellar radiation field (ISRF). In addition, the calculated grain opacities required to reproduce the far-IR fluxes in the Cloudy models are a few factors larger than that calculated for standard ISM graphite and silicate grains. This result suggests that the grains in dense regions are coated with water and ammonia ices, increasing their sizes and opacities. The Cloudy models also predict mm-wavelength CO line strengths for comparison with published observations at the IRAM 30-m telescope. In order to reproduce the observed CO line strengths for cores in MCLD 123.5+24.9, the models require that CO molecules be partially frozen out onto the grains. This result places age constraints upon the cores. We have also modeled CO emission from inter-core regions in MCLD 123.5+24.9. For these regions, the models significantly under predict the observed CO line strengths unless the molecular gas is clumped into high-density regions.

138.06 – KAT-7 Science Verification: Using HI Observations of NGC 3109 to Understand its Kinematics and Mass Distribution

Danielle M. Lucero[1], Claude Carignan[1], Kelley M. Hess[1], Bradley S. Frank[1], Toky H. Randriamampandry[1], Sharmila Goedhart[2], Sean S. Passmoor[2]
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HI observations of the Magellanic-type spiral NGC 3109, obtained with the seven dish Karoo Array Telescope (KAT-7), are used to analyze its mass distribution. Our results are compared to those obtained using Very Large Array (VLA) data. KAT-7 is a pathfinder of the Square Kilometer Array precursor MeerKAT, which is under construction. The short baselines and low system temperature of the telescope make it sensitive to large-scale, low surface brightness emission. The new observations with KAT-7 allow the measurement of the rotation curve (RC) of NGC 3109 out to 32', doubling the angular extent of existing measurements. A total HI mass of 4.6×10^8 M$_{™}$ is derived, 40% more than what is detected by the VLA observations. The observationally motivated pseudo-isothermal dark matter halo model can reproduce the observed RC very well, but the cosmologically motivated Navarro-Frenk-White DM model gives a much poorer fit to the data. While having a more accurate gas distribution has reduced the discrepancy between the observed RC and the MOdified Newtonian Dynamics (MOND) models, this is done at the expense of having to use unrealistic mass-to-light ratios for the stellar disk and/or very large values for the MOND universal constant a$_0$. Different distances or HI contents cannot reconcile MOND with the observed kinematics, in view of the small errors on these two quantities. As with many slowly rotating gas-rich galaxies studied recently, the present result for NGC 3109 continues to pose a serious challenge to the MOND theory.

139 – New Science from the CLASH/CANDELS Multi-Cycle Treasury Programs

Special Session – Maryland Ballroom B – 06 Jan 2014 02:00 pm to 03:30 pm

The Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS) and the Cluster Lensing and Supernova survey with Hubble (CLASH) will complete their 3-year Hubble Space Telescope observations in 2013. A special session highlighting the scientific results derived from these two HST Multi-cycle Treasury Programs will be very timely. The two surveys offer a complementary approach to studying cosmic evolution, with CANDELS surveying some of the best-studied fields with the deepest multi-wavelength data, and CLASH surveying some of the most massive and relaxed moderate-redshift gravitational-lens clusters. These programs provide complementary approaches to finding and studying very high redshift (z>5) galaxies, studying structure of galaxies at redshifts $0.5 1. Data from both surveys are non-proprietary, and have already been the subject of intense study. Eight oral presentations will include the latest constraints on luminosity functions and stellar populations in the most distant galaxies, important new constraints on galaxy and cluster formation and their implications for structure formation, and the latest estimates of the evolution Type Ia supernova rate at high redshift.

139.01 – The Concentration-Mass Relation from CLASH

Julian Merten[1]
1. JPL / Caltech, Pasadena, CA, United States.
Contributing teams: CLASH

Clusters of galaxies, as the most massive gravitationally bound structures in the observable Universe, are sensitive probles of structure formation scenarios. The Cluster Lensing and Supernova Survey with Hubble (CLASH) maps the matter distribution in 25 rich galaxy clusters using gravitational lensing measurements derived from a combination of multi-band HST and Subaru imaging. This combination of data allows for a reliable multi-scale reconstruction of the dark matter density distribution over three decades in radius - from the central 50 kpc out to beyond the cluster virial radius. We present constraints the cluster mass-concentration (M-c) relation for an x-ray selected subset of the full CLASH sample (20 of the 25 clusters). The concentration parameter is defined as the spatial extend of the full cluster halo divided by the spatial extent of the halo core and can be analyzed as a function of total halo mass and redshift. Former studies have suggested a strong tension in the observed M-c relation when compared to expectations derived from numerical simulations. We will present our current constraints on the M-c relation along with comparisons to the latest theoretical expectations.

139.02 – Studying Galaxy Evolution at High-Redshift with CANDELS

Steven L. Finkelstein[1]
1. University of Texas, Austin, TX, United States.
Contributing teams: CANDELS Team

The availability of deep and wide near-infrared imaging from CANDELS has allowed the first in-depth studies of galaxy evolution out to z=8. The completion of CANDELS has provided the largest sample of distant galaxies yet compiled, which has allowed the investigation into the bright-end of the luminosity function at z=7 for the first time, which can provide important constraints on the process of galaxy formation. Additionally, these bright galaxies are excellent candidates for spectroscopic followup, and I will present recent results on that front. Finally, by studying the colors of the detected galaxies, we can investigate the evolution of physical properties within these galaxies, and we find that galaxies on average appear to have star-formation rates which rise with time, which naturally lead to correlations between their star-formation rates and stellar masses.

139.03 – High Redshift Galaxies in CLASH

Larry D. Bradley[1]
1. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: CLASH Team

Characterizing the evolution of galaxies at early cosmic times is one of the most exciting frontiers of observational cosmology. While ultradeep HST images have revolutionized our knowledge about high-redshift galaxies, searching for and studying high-redshift galaxies remains a challenging enterprise due to their faint luminosities and low volume densities. A promising and efficient approach to detect and study the properties of faint high-redshift galaxies is to take advantage of gravitational lensing by massive galaxy clusters. The high-quality HST optical and NIR multiband observations of 25 lensing clusters obtained by the CLASH MCT program, combined with complementary Spitzer observations, are allowing for substantial advances, including some of the first studies of galaxies at z~9-11, constraints on the cosmic star formation rate density, and stellar masses estimates of faint z>~6 galaxies. In this presentation, I will highlight some new results on the number densities of a large sample of lensed z~6-8 galaxies and the prevalence of high equivalent width nebular emission lines in z~7 galaxies.

139.04 – Confronting theoretical models with CANDELS observations

Yu Lu[1]

1. Stanford University, Stanford, CA, United States.
Contributing teams: The CANDELS collaboration

Current galaxy formation models contain large uncertainties in modeling gas accretion, star formation and feedback processes. These uncertainties can only be constrained by comprehensive and careful model-data comparisons. Three independently developed semi-analytic galaxy formation models are adopted to make predictions for CANDELS observations. A comparison study involving the three different models reveals both common features shared by the models and discrepancies between the models. The similarities in the predicted stellar mass functions indicate strong degeneracies between the models, which can only be broken by accurate measurements of the stellar mass functions at multiple redshifts. On the other hand, the models show large discrepancies in their predicted star formation histories and metallicity-stellar mass relations. These discrepancies stem from the uncertainties in modeling gas accretion and galactic outflow powered by feedback. The model comparisons suggest that, other than directly constraining inflow and outflow in observation, more accurate observational measurements for stellar mass, star formation rate and metallicity of galaxies in a large range of cosmic epoch will discriminate between models. Our study involving multiple models and exploration of the high-dimensional parameter space demonstrates that analysis of the full CANDELS dataset, including a self-consistent treatment of star formation rates, stellar masses, galaxy sizes, metallicity relations and their evolution across a broad redshift range, is likely to significantly tighten the data constraints and shed light on understanding the physics governing galaxy formation.

139.05 – Baryon-Derived Scaling Relations from CLASH

Nicole G. Czakon[1], Megan Donahue[2], Elinor Medezinski[3]
1. California Institute of Technology, Pasadena, CA, United States. 2. Michigan State University, Lansing, MI, United States. 3. Johns Hopkins University, Baltimore, MD, United States.
Contributing teams: CLASH,Bolocam

The CLASH observing program has produced a unique data set which allows the accurate calibration of a large set of galaxy cluster masses. The cosmological and astrophysical implications of these measurements extend far beyond HST-only science. To capitalize on the astronomy community's interest in the CLASH data products, our collaboration has assembled a team of experts across many different observational cluster probes, including: strong lensing, weak lensing, X-ray, and the Sunyaev-Zel'dovich Effect (SZE). By combining weak- and strong-lensing measurements, full cluster profiles can be constrained from the inner tens of kpc out to several Mpc. This has important implications in cross-probe analyses as different observational probes are sensitive to different regions of a cluster's mass profile. Another goal of the CLASH program is to characterize the level of hydrostatic mass bias in X-ray measurements. This is important as hydrostatic mass estimates are commonly used to calibrate X-ray and SZE cluster studies. In my talk, I will report on the status of several cross-probe scaling relations comparing the CLASH lensing masses and various baryonic cluster mass probes, including: optical richness, X-ray, and SZE observations of the full CLASH cluster catalog. The results of these investigations will be interesting for both large-scale surveys and individual cluster studies, when high quality lensing data is unavailable.

139.06 – Type Ia Supernovae in the Early Universe from CANDELS

Steven A. Rodney[1]
1. Johns Hopkins University, Baltimore, MD, United States.
Contributing teams: The CANDELS+CLASH SN Team

Using 3 years of infrared HST imaging, we have discovered ~100 new supernovae (SNe) in the 5 CANDELS fields, including new record holders for the most distant Type Ia SNe (SN Ia). From this sample we have derived a measurement of the SN Ia rate reaching for the first time above redshift 2. By stretching into the early universe, these data offer unique leverage for testing models of the SN Ia progenitor system. I will present our new constraints on the fraction of SN Ia progenitors that are "prompt": exploding within 500 Myr of their formation. In addition, I will discuss the lessons learned on how to analyze SNe at high redshift, and our extension into the HST Frontier Field survey.

139.07 – The CLASH Type-Ia Supernova Rates Out to Redshift 2.4

Or Graur[1, 2]
1. The Johns Hopkins University, Baltimore, MD, United States. 2. Tel Aviv University, Tel Aviv, Israel.
Contributing teams: CLASH, CANDELS

The star that explodes as a Type-Ia supernova (SN Ia) is probably a carbon-oxygen white dwarf. In order for the white dwarf to explode, most scenarios assume that it accretes matter from a binary companion, though the nature of the companion and the accretion process are still unclear. One way to constrain existing progenitor models is to recover the delay-time distribution (DTD), the function that connects between the star-formation history (SFH) and SN Ia rates of a specific stellar

population. As part of the Cluster Lensing And Supernova survey with Hubble (CLASH), we conducted a SN survey in blank fields imaged, in parallel to the 25 galaxy-cluster fields, with the Advanced Camera for Surveys and Wide Field Camera 3 on the Hubble Space Telescope. We discovered 27 SNe in the blank fields and used them to measure SN Ia rates out to redshift 1.8 and an upper limit on the rate in the redshift range $1.8 < z < 2.4$. Our SN Ia rates are consistent with those measured by the HST/GOODS survey (Dahlen et al. 2004, 2008) and the Subaru Deep Field survey (Poznanski et al. 2007; Graur et al. 2011). We use our SN Ia rates, along with previous measurements from the literature and a variety of cosmic SFHs, to test different DTD models. We find that a power-law DTD with an index of ? -1 is consistent with the SN Ia rates, as are the shapes of the double-degenerate DTD models produced by binary population synthesis (BPS) simulations. However, all BPS single-degenerate DTDs are ruled out at a >99% significance level.

139.08 – CANDELS Measurements of Structure and Morphology Over Cosmic Time

Jeyhan S. Kartaltepe[1]
1. National Optical Astronomy Observatory, Tucson, AZ, United States.
Contributing teams: The CANDELS Collaboration

One of the main goals of the CANDELS survey is understanding galaxy structure and morphology and how it has changed over the age of the universe. The exquisite wide-field high resolution near-infrared imaging from HST/WFC3 has allowed us to study the rest-frame optical morphology of large numbers of galaxies at cosmic high noon (z~2) for the first time. In this talk, we will present the measurements of structure and morphology that have been performed by the CANDELS collaboration, including an ambitious program to visually classify galaxies in all of the fields and both parametric and non-parametric measures of morphology. Finally, we will present some of the scientific highlights resulting from these measures.

140 – Pulsars & Neutron Stars II
Oral Session – National Harbor 13 – 06 Jan 2014 02:00 pm to 03:30 pm

140.01 – Pulsar Observations Using the First Station of the Long Wavelength Array

Kevin Stovall[1], Paul Demorest[2], Jayce Dowell[1], Paul S. Ray[3], Frank Schinzel[1], Gregory B. Taylor[1]
1. University of New Mexico, Albuquerque, NM, United States. 2. National Radio Astronomy Observatory, Charlottesville, VA, United States. 3. Naval Research Laboratory, Washington, DC, United States.

Radio pulsars have largely been unexplored at frequencies below 100 MHz. However, observations at such frequencies can provide extensive information about pulsars as well as the interstellar medium that their signals propagate through. We have begun to use the first station of the Long Wavelength Array (LWA1) to observe radio pulsars and have detected over 30 pulsars within the 20-88 MHz frequency range. This talk will present initial results from these observations, which include detections of pulsars with spin periods from about 5 milliseconds to 4 seconds. Construction of the LWA has been supported by the Office of Naval Research under Contract N00014-07-C-0147. Support for operations and continuing development of the LWA1 is provided by the National Science Foundation under grants AST-1139963 and AST-1139974 of the University Radio Observatory program.

140.02 – Observations of Rotating Radio Transients Using the Long Wavelength Array

Rossina B. Miller[1], Maura McLaughlin[1]
1. West Virginia University, Morgantown, WV, United States.

Rotating radio transients (RRATs) are a type of pulsar discovered through their isolated single pulses. Currently over 80 of these objects are known, but less than half have timing solutions as their sporadic nature makes obtaining solutions difficult. We present the first observations of RRATS with the Long Wavelength Array (LWA), the properties of these objects, and the potential for long-term timing at very low frequencies.

140.03 – Detection of Pulsed Emission from the Millisecond Pulsar PSR J2145-0750 Below 100 MHz

Gregory B. Taylor[1], Jayce Dowell[1]
1. Univ. of New Mexico, Albuquerque, NM, United States.
Contributing teams: Long Wavelength Array

Millisecond pulsars (MPSs) are distinguished from normal pulsars by faster rotation periods, weaker magnetic fields, and flux density spectra that are well fit by a single power law down to 100 MHz. Below 100 MHz some MSPs show a break in the power law, however, additional observations, particularly of the pulse profile, are needed in this frequency range to provide better constraints on emission mechanisms. The first station of the Long Wavelength Array, LWA1, is a low frequency telescope that is ideally suited to address these questions. We present recent results from LWA1 on the millisecond pulsar PSR J2145-0750. Using coherent dedispersion we detected pulsed emission between 37 and 85 MHz. From this we derive flux densities and pulse profiles at 41, 57, 65, 73, and 81 MHz. We find that the flux density spectrum of PSR J2145-0750 appears to flatten below 100 MHz relative to the spectral index of ~-1.6 found in the literature. We also find that the pulse profile shows little evolution over this frequency range and is similar to profiles found at 102 MHz. We also discuss the prospects for precision dispersion measure monitoring at these frequencies. Construction of the LWA has been supported by the Office of Naval Research under Contract N00014-07-C-0147. Support for operations and continuing development of the LWA1 is provided by the National Science Foundation under grants AST-1139963 and AST-1139974 of the University Radio Observatory program.

140.04 – A Millisecond Pulsar in a Stellar Triple System

Scott M. Ransom[1], Ingrid H. Stairs[2], Anne Archibald[3], Jason Hessels[3], David L. Kaplan[4], Marten van Kerkwijk[5], Jason Boyles[6], Duncan Lorimer[7], Adam Deller[3], Shami Chatterjee[8]
1. NRAO, Charlottesville, VA, United States. 2. U. British Columbia, Vancouver, BC, Canada. 3. ASTRON, Dwingeloo, Netherlands. 4. U. Wisconsin-Milwaukee, Milwaukee, WI, United States. 5. U. Toronto, Toronto, ON, Canada. 6. W. Kentucky U., Bowling Green, KY, United States. 7. W. Virginia U., Morgantown, WV, United States. 8. Cornell U., Ithaca, NY, United States.
Contributing teams: The GBT Driftscan Collaboration

In late 2011, as part of the Green Bank Telescope 350MHz Driftscan survey, we uncovered a fast, bright, and so-far unique millisecond pulsar in a hierarchical triple system with two white dwarf companions. Since that time, using a variety of

telescopes and a huge number of observations, we have fully "solved" the system, PSR J0337+1715. Gravitational interactions between the 1.6-day and 327-day orbits and the relativistic transverse Doppler effect of the pulsar are detected with extremely high precision, providing all masses and inclinations to four significant figures. Fitting the data with a 3-body integrator, pulse arrival times are predicted with microsecond-level or better precision. The compact natures of the three stars and their very different gravitational binding energies ($3GM/5Rc^2$; ~0.1 for the pulsar and ~$1x10^{-4}$ for the white dwarfs) will likely provide the best tests so far of the Strong Equivalence Principle and therefore strong constraints on alternative metric and scalar-tensor theories of gravity. High-quality optical observations of the hot inner white dwarf combined with an upcoming precise distance measurement from the VLBA will allow the system to be used as a calibrator for low-mass Helium white dwarfs. Finally, the exquisitely measured properties of the system will allow detailed investigations into its likely very strange evolutionary history.

140.05 – PSR J2021+4026 in the Gamma Cygni region: the first variable gamma-ray pulsar seen by the Fermi Large Area Telescope

Massimiliano Razzano[1], Luigi Tibaldo[2]
1. University of Pisa & INFN-Pisa, Pisa, Italy. 2. KIPAC/SLAC, Menlo Park, CA, United States.
Contributing teams: Fermi-LAT Collaboration

Recent radio and X-ray observations have unveiled new aspects of pulsar variability, including mode changes and intermittent behavior. These phenomena are powerful probes of pulsar magnetospheres and represent a challenge for current emission models. In the gamma-ray domain where the bulk of their spindown luminosity is radiated, however, pulsars were believed to be steady emitters on timescales longer than those needed for their detections. We present the discovery of gamma-ray variability from the Geminga-like pulsar PSR J2021+4026 in the Gamma Cygni region. The pulsar flux above 100 MeV decreased by about 20% near 2011 October 16th (MJD 55850), over a time scale shorter than a week. At the same time, the spindown rate increased by 4% and there were significant changes in the pulse profile. We speculate that the flux change is due to a modification in the emission beaming precipitated by a shift in the magnetic field structure, leading to a change of either effective magnetic inclination or effective current. This "jump" of PSR J2021+4026 breaks the axiom of pulsars as steady gamma-ray emitters, opening new avenues for investigating pulsar magnetospheres through variability studies at gamma-ray energies.

140.06 – Discovery of a Highly Eccentric Binary Millisecond Pulsar in a Gamma-Ray-Detected Globular Cluster

Megan E. DeCesar[1], Scott M. Ransom[2], Paul S. Ray[3], David L. Kaplan[1]
1. Physics, University of Wisconsin-Milwaukee, Shorewood, WI, United States. 2. National Radio Astronomy Observatory, Charlottesville, VA, United States. 3. Naval Research Laboratory, Washington, DC, United States.
Contributing teams: Fermi Large Area Telescope Collaboration

We report on the Green Bank Telescope discovery of a highly eccentric binary millisecond pulsar (MSP) in NGC 6652, the first MSP to be detected in this globular cluster. The pulsar search was guided by the Fermi Large Area Telescope, which detected NGC 6652 at GeV energies, identifying the cluster as a likely host of a population of gamma-ray-emitting MSPs. Initial timing of the MSP yielded an eccentricity of ~0.95 and a minimum companion mass of 0.73 solar masses, assuming a neutron star mass of 1.4 solar masses. These results strongly indicate that the pulsar has undergone one or more companion exchanges in the dense stellar environment of the cluster, and that the current companion is a compact object, likely a massive white dwarf or a neutron star. Further timing of this system will result in a measurement of the post-Keplerian rate of periastron advance and therefore a direct measurement of the total system mass, allowing additional constraints to be placed on both the pulsar and companion masses. The timing solution will also be used to search for gamma-ray pulsations from the MSP.

140.07 – Discovery of the radio and gamma-ray pulsar PSR J2339-0533 associated with the Fermi LAT bright source 0FGL J2339.8-0530

Paul S. Ray[1], Andrea M. Belfiore[2], Pablo Saz Parkinson[2, 9], Emil Polisensky[1], Scott M. Ransom[5], Roger W. Romani[6], Jason Hessels[4], Massimiliano Razzano[7], Bhaswati Bhattacharyya[3], Jayanta Roy[3], Ismael Cognard[8]
1. NRL, Washington, DC, United States. 2. UCSC, Santa Cruz, CA, United States. 3. NCRA, Pune, India. 4. ASTRON, Dwingeloo, Netherlands. 5. NRAO, Charlottesville, VA, United States. 6. Stanford, Stanford, CA, United States. 7. University of Pisa & INFN, Pisa, Italy. 8. CNRS, Orleans, France. 9. University of Hong Kong, Hong Kong, Hong Kong.
Contributing teams: Fermi Pulsar Search Consortium

We report the detection of radio and gamma-ray pulsations from the bright Fermi LAT source 0FGL J2339.8-0530. This source was one of the bright gamma-ray sources uncovered in the first 3 months of Fermi LAT survey mode observations. Deep X-ray and optical follow up observations led to the identification of the probable counterpart that showed all the characteristics of a millisecond pulsar in a 4.6 hour binary orbit, except for pulsations. We have discovered 2.88 ms radio pulsations in an observation with the NRAO Green Bank Telescope at 820 MHz, confirming this source as a pulsar and demonstrating that the companion was substantially more massive than models of the optical light curve had suggested. With the pulse period and orbital parameters highly constrained, we were then able to discover the gamma-ray pulsations in the LAT data, confirming the identification with 0FGL J2339.8-0530. Detailed timing of the pulsar using the LAT data provided a measurement of the spin down rate, showing that this is an energetic millisecond pulsar with spin down luminosity 2.3E34 erg/s. We discuss the improvement in our understanding of the system as a result of the radio and gamma-ray pulsation discoveries.

140.08 – Gamma-Ray Pulsar Emission: From Theory to Observations

Constantinos Kalapotharakos[1,2], Alice K. Harding[2], Demosthenes Kazanas[2]
1. University of Maryland, College Park, MD, United States. 2. Goddard Space Flight Center, NASA, Greenbelt, MD, United States.

We present numerical models of dissipative 3D pulsar magnetospheres which are then employed to account for the observations. Using a variety of prescriptions to relate the current density J to the fields E, B we produce families of solutions covering the entire spectrum between the vacuum retarded dipole and the force-free solutions. These solutions provide also the distribution of electric field components parallel to the magnetic field B, which accelerate the radiating particles. Using these detailed dissipative magnetospheric models we generate model gamma-ray light curves by calculating realistic trajectories of radiating particles and the corresponding Lorentz factors under the influence of both the accelerating electric fields E and radiation-reaction effects. Assuming the radio emission to originate along the magnetic dipole axis and near the surface of the pulsar, we compute the lags between the radio and gamma-ray light curves. We find that agreement of the observed radio - gamma-ray lags demands Force-Free conditions (negligible acceleration) interior to the light cylinder and high but finite conductivity outside the light-cylinder, with most of gamma-ray emission originating in regions near the equatorial current sheet between 1 and 2 light-cylinder radii.

141 – The Dark Energy Camera and the Dark Energy Survey

Special Session – National Harbor 10 – 06 Jan 2014 02:00 pm to 03:30 pm

The Dark Energy Camera is a 3-square-degree imager on the CTIO Blanco 4-meter telescope, now fully commissioned and available for community use. The Dark Energy Survey is a five-year, 5000-square-degree multicolor survey which began in August 2013, with the primary goal of exploring the cause of the Hubble acceleration. This session will describe the capabilities and on-sky performance of the camera and the new active optics system; the progress of the Survey and the data to become publicly available; and initial science results from the Survey.

141.01 – Overview of DECam and DES

Gary Bernstein[1]
1. Univ. of Pennsylvania, Philadelphia, PA, United States.
Contributing teams: The Dark Energy Survey Collaboration

The Dark Energy Camera is a 3-square-degree CCD camera now operational on the 4-meter Blanco telescope in Chile. The Dark Energy Survey, a project to use DECam to survey 5000 square degrees of sky plus a time-domain survey of 30 square degrees over the next five years. I will describe the characteristics and performance of DECam to date, and give an overview of the goals and methods of the Survey, as well as the data products to be produced and released.

141.02 – DECam Image Quality

Aaron Roodman[1]
1. Kavli Institute for Particle Astrophysics & Cosmology, SLAC National Accelerator Laboratory, Stanford University, Menlo Park, CA, United States.
Contributing teams: Dark Energy Survey Collaboration

The Dark Energy Camera (DECam) is a three square degree, 520 megapixel, camera installed and commissioned in 2012 on the Blanco 4-meter telescope at CTIO. The image quality contribution from the optics and CCDs is expected to be better then 0.55 arcsec across the entire field of view. DECam also has eight CCDs placed out of focus to measure the optical wavefront and to enable active control of the camera's focus and alignment. A summary of the delivered image quality from early data taken for the Dark Energy Survey will be presented. The routine operation of the active optics system will be described, and the resulting characterization of the optical wavefront will be shown. Lastly preliminary results connecting the measured wavefront with the point spread function will be presented.

141.03 – DES Gravitational Lensing Results

Peter Melchior[1]
1. Center for Cosmology and Astro-Particle Physics, The Ohio State University, Columbus, OH, United States.

I will give an overview of the current state of the weak-lensing data analysis, focussing on systematics tests to validate the quality of the survey images, and highlight the first results obtained from observations during the Science Verification period.

141.04 – DES Large-scale Structure Results

Ignacio Sevilla[1]
1. CIEMAT, Madrid, Spain.
Contributing teams: The Dark Energy Survey Collaboration

The Dark Energy Survey (DES) is a 5000 square degree photometric survey with the goal of measuring the parameters of dark energy. In August 2013, it began survey operations using the new DECam imager on the Blanco 4m telescope at the Cerro Tololo Interamerican Observatory. Making measurements of Large Scale Structure using galaxy clustering is one of the primary science drivers of the experiment. When combined with other Dark Energy probes made with the same data, these measurements will enable either a strong validation of the current LCDM paradigm, or will show inconsistencies pointing towards a cosmology based on modified gravity or an evolving Dark Energy equation of state. Although experiment design concentrated on enabling BAO measurements with high statistical precision, current scientific developments mean measurements made by cross-correlation with CMB datasets, or using redshift-space distortions to explore the growth of structure, will also be of high interest. In this contribution, we will describe ongoing efforts at making measurements using the initial Science Verification dataset (aproximately 150 square degrees) with special focus on understanding the systematics that will be important for later datasets.

141.05 – DES Supernova Results

Christopher D'Andrea[1]
1. Institute for Cosmology and Gravitation, University of Portsmouth, Portsmouth, Hants, UK, United Kingdom.
Contributing teams: The Dark Energy Survey

The Dark Energy Survey Supernova program (DES SN) will discover approximately 3500 Type Ia supernovae with well-sampled multi-color light curves in the redshift range $0.2 < z < 1.2$ over its five year duration. The large field of view and high z-band sensitivity of the Dark Energy Camera, combined with the precision photometry of DES and an improved handling of systematic uncertainties will allow DES SN to provide the strongest constraints on supernova cosmology to date. One of the main challenges for DES SN will be accurate classification of such a large number of faint transients. I will describe the unique spectroscopic follow-up strategy that we are employing, with emphasis on the 100 night, survey-status program at AAT which began in September. I will present preliminary supernova results obtained from the DES Science Verification period and the beginning of DES Year 1.

141.06 – DES Galaxy Cluster Results

Eli S. Rykoff[1]
1. SLAC National Accelerator Laboratory, Menlo Park, CA, United States.
Contributing teams: DES Cluster Working Group

The Dark Energy Survey (DES) is a 5 year, 5000 square degree photometric survey in 5 bands (grizY), with the primary goals of exploring the cause of cosmic acceleration and to trace the growth of structure. Probing the growth of structure via clusters of galaxies, the most massive bound structures in the Universe, is one of the key Dark Energy probes of DES as they provide one of the best ways to distinguish between a cosmological constant and deviations from General Relativity on cosmological scales. From November 2012 through February 2013 DES performed a "science verification" observing campaign (SVA1), covering over 100 deg^2 in the southern sky to full DES depth. Here we describe early results from galaxy clusters from SVA1, including a new measurement of the red galaxy conditional luminosity function to z~1. We also show how these results inform our catalog simulation work for better predictions of the DES performance after the full 5 year survey.

159 – Developing Our Own Future: Undergraduate Research and Enrichment Through Peer-Led Programs

Special Session – Maryland 3 – 06 Jan 2014 02:00 pm to 03:30 pm

This session is a collaboration between undergraduates at astronomy departments across country to showcase undergraduate research and initiative. Having undergraduate research is essential to getting into a graduate program. Because many students go into research, getting experience as an undergraduate helps them determine the path they take after their undergraduate degree. We especially focus on the social and academic support, and career networking, aspects of undergraduate-led programs. Undergraduate research and peer-mentoring helps to promote science to a new generation of astronomers. The session features speakers from multiple undergraduate astronomy programs, and will particularly focus on the benefits and potential of peer networks as opposed to purely faculty-led initiatives. This session will build on the regular oral session presented by the University of Arizona Astronomy Club at the 221st AAS meeting in Indianapolis in June.

159.01 – Welcome Address

Allison P. Towner[1], Kevin Hardegree-Ullman[2], Gina Brissenden[3, 1], Amanda Walker-LaFollette[1]
1. University of Arizona, Tucson, AZ, United States. 2. University of Toledo, Toledo, OH, United States. 3. Center for Astronomy Education, Tucson, AZ, United States.

The Special Session "Developing Our Own Future: Undergraduate Research and Enrichment Through Peer-Led Programs" is a collaborative session with undergraduate presenters from a diverse pool of institutions all around the United States. These undergraduates are presenting aspects of their peer-led organizations, programs, or projects, and represent the next generation of professional astronomers. This Welcome Address will give a general overview of the session – both Oral and Poster presentations – and will discuss the motivations of the Session Organizers for creating this session. It will also discuss the hoped-for results and consequences of gathering so many undergraduates together to present and discuss their peer-led initiatives on a national stage.

159.02 – The League of Astronomers

Nancy H. Thomas[1], Andrew Brandel[1], Anthony M. Paat[1], Denise Schmitz[1], Ramon Sharma[1], Juan Trujillo[1], Christopher S. Laws[1]
1. University of Washington, Seattle, WA, United States.

The League of Astronomers is committed to engaging the University of Washington (UW) and the greater Seattle communities through outreach, research, and events. Since its re-founding two years ago, the LOA has provided a clear connection between the UW Astronomy Department, undergraduate students, and members of the public. Weekly outreach activities such as public star parties and planetarium talks in both the UW Planetarium and the Mobile Planetarium have connected enthusiastic LOA volunteers with hundreds of public observers. In addition, collaboration with organizations like the Seattle Astronomical Society and the UW Society of Physics Students has allowed the LOA to reach an even greater audience. The club also provides opportunities for undergraduate students to participate in research projects. The UW Student Radio Telescope (SRT) and the Manastash Ridge Observatory (MRO) both allow students to practice collecting their own data and turning it into a completed project. Students have presented many of these research projects at venues like the UW Undergraduate Research Symposium and meetings of the American Astronomical Society. For example, the LOA will be observing newly discovered globular clusters at the Dominion Astrophysical Observatory (DAO) in Victoria, B.C. and constructing color-magnitude diagrams. The LOA also helps engage students with the Astronomy major through a variety of events. Bimonthly seminars led by graduate students on their research and personal experiences in the field showcase the variety of options available for students in astronomy. Social events hosted by the club encourage peer mentoring and a sense of community among the Astronomy Department's undergraduate and graduate students. As a part of one of the nation's largest undergraduate astronomy programs, members of the League of Astronomers have a unique opportunity to connect and interact with not only the Seattle public but also the greater astronomical community.

159.03 – Bridging the gap between undergrads and grads: The mentor next door

Aaron Gruberg[1]
1. San Francisco State Univ, San Francisco, CA, United States.
Contributing teams: Aaron White

Astronomy undergraduates must adapt to countless changes both in work and life as they transition into upper division students. Besides managing a larger, more involved workload, they must begin preparing for their future with things like the Physics GRE, applications for graduate schools, conference attendance/preparation, or finding jobs outside of academia. These experiences come very rapidly, and often without warning, leaving students in a constant uphill struggle, unsure of what challenges lie before them, many of which they may not have even heard of yet. Graduate students have been through all of these experiences only a few years prior, giving them great potential for mentorship, informing undergrads of exactly what challenges lie ahead, and the best ways to prepare and meet them. These exchanges are disappointingly uncommon though, as direct interaction between upper division undergrads and grads is often fleeting, if not unheard of outside of

student/TA relationships. This unspoken barrier between undergrads and grads can leave students studying and working just doors apart, yet never meeting, barring them from taking advantage of the invaluable exchanges they could be participating in. We will describe how the terminal masters program at San Francisco State has helped create a unique environment which has largely broken this divide between undergrads and grads, allowing for incredible mentorship as well as collaboration and exchange of ideas from both sides. We offer advice for building these relationships between astronomy students of any kind, giving suggestions undergrads, grads, or faculty can aim for to help forge these relationships. The oral portion of this presentation will discuss the benefits undergrads can receive from this exchange. We will draw on the use of life experiences inside as well as outside of academia and show how the undergraduate experience can be broadened.

159.04 – PEER DEVELOPMENT OF UNDERGRADUATE ASTRONOMERS AND PHYSICISTS AT THE UNIVERSITY OF WISCONSIN – MADISON

Melissa Abler[1]

1. Univ of Wisconsin, Madison, Madison, WI, United States.

Contributing teams: Physics Club of UW-Madison

The physics club at the University of Wisconsin – Madison is actively engaged in many peer-led activities that foster development of career-oriented skills. The Garage Physics program utilizes old, unwanted laboratory equipment to enable students' in-depth exploration of classroom experiments and to investigate their own ideas. The ability to explore individual interests independently further develops research skills and assists in students' retention of classroom knowledge. The finished products are then presented to the public at various science education and outreach events throughout the community. Sharing self-motivated projects with the public not only enhances public knowledge, understanding, and interest, but also develops valuable communication skills in the students. A self-developed introductory research guidebook helps younger club members find a mentor in the astronomy or physics departments and begin working in a research group. Senior undergraduate students also facilitate a panel each semester to discuss their experiences in acquiring and maintaining an undergraduate research position.

159.05 – Peer mentoring of telescope operations and data reduction at Western Kentucky University

Joshua Williams[1], Michael T. Carini[1]

1. , Bowling Green, KY, United States.

Peer mentoring plays an important role in the astronomy program at Western Kentucky University. I will describe how undergraduates teach and mentor other undergraduates the basics of operating our 0.6m telescope and data reduction (IRAF) techniques. This peer to peer mentoring creates a community of undergraduate astronomy scholars at WKU. These scholars bond and help each other with research, coursework, social, and personal issues. This community atmosphere helps to draw in and retain other students interested in astronomy and other STEM careers.

159.06 – The Society of Astronomy Students: From the Ground Up

Shannon Rees[1], Mercedes Maldonado[1], Dana Beasley[1], Angelica Campos[1], Amber Medina[1], Nancy J. Chanover[1]

1. New Mexico State Univ, Las Cruces, NM, United States.

The Society of Astronomy Students (SAS) at New Mexico State University (NMSU) was founded in October of 2012 and chartered in January 2013. New Mexico State University is located in Las Cruces, New Mexico, which is a small city with a population of just over 100,000. The main campus at NMSU has an enrollment of approximately 14,300 undergraduate students and 3,375 graduate students. The NMSU Astronomy Department is a vibrant research environment that offers Ph.D. and M.S. Graduate degrees and serves the undergraduate population through a large number of general education courses. Although there is no undergraduate major in Astronomy at NMSU, students can earn an undergraduate Astronomy Minor. The SAS was conceived as a way to provide undergraduates with an interest in astronomy a way to communicate, network, and provide mutual support. Currently, the SAS is in its second year of being a chartered organization and has about 18 active members, about half of whom are planning on pursuing an Astronomy Minor. The SAS is striving to become one of the most active clubs on the NMSU campus in order to raise awareness about Astronomy and encourage the option of pursuing the Astronomy Minor. One of the main focus areas of the SAS is to be involved in both astronomy-related and non-astronomy-related public outreach and community service events. Since the clubs inception, the SAS members have contributed a total of over 120 volunteer hours. We do many outreach events with the elementary and middle schools around the community; these events are done jointly with the Astronomy Graduate Student Organization at NMSU. In the near future, the SAS is also planning a wide range of activities, including a guest speaker series at weekly club meetings, tours of the Apache Point Observatory, full moon outings, and participation in amateur astronomy events such as the Messier Marathon. This presentation will include an overview of the club's history, accomplishments, and future activities.

159.07 – Results and Implications of Seven Years of the University of Arizona Astronomy Club

Amanda Walker-LaFollette[1], Allison P. Towner[1], Kevin Hardegree-Ullman[2], Gina Brissenden[3, 1]
1. University of Arizona/Steward Observatory, Tucson, AZ, United States. 2. University of Toledo, Toledo, OH, United States. 3. Center for Astronomy Education, Tucson, AZ, United States.

Participation in an undergraduate astronomy club or organization, be it social, academic, outreach-, or research-oriented, can be extremely beneficial to astronomy students. In this talk, we present the numerical results of the past seven years of University of Arizona Astronomy Club activities, particularly those relating to published papers, poster presentations, attendance at AAS meetings, and retention within the major. We also discuss less-quantifiable results, such as social, academic, and emotional support for club members. Finally, we highlight the efforts being performed by undergraduates at institutions all around the country, as presented in this Session.

142 – Henry Norris Russell Lecture: New Developments in Galactic Archaeology

Plenary Session – Potomac Ballroom A – 06 Jan 2014 03:40 pm to 04:30 pm

142.01 – New Developments in Galactic Archaeology

Kenneth C. Freeman[1]

1. Australian National Univ., Weston Creek, ACT, Australia.

Contributing teams: HERMES/GALAH team

The goal of Galactic Archaeology is to unravel observationally the events that occurred during the assembly of the Milky Way. For example, how did the star formation rate and the mass spectrum of the star-forming clusters change with time since the Galaxy began to form, how much did minor mergers and accretion of satellite galaxies contribute to the stellar content of the Galactic components, and how did the chemical properties of the Galaxy evolve? The data for Galactic Archaeology include the phase space coordinates of stars (position and velocity) and the chemical space coordinates (abundances of up to about 30 chemical elements). Although we know that the distribution of individual elements contains important information about the star formation history and chemical evolution of the Galaxy, the available data for large samples of stars has so far restricted the use of chemical space data mainly to the overall metallicity and the alpha-element enhancement. We are entering an era of large high-resolution spectroscopic surveys in which the abundances of many elements from all of the major nucleosynthesis processes will be measured. It will be possible to use chemical tagging techniques to identify the debris of individual dispersed star forming aggregates. In combination with astrometry from the Gaia mission, it will be possible to derive ages for this recovered star formation debris, and build up the star formation history of the regions of the Milky Way accessible to these large surveys. The Galactic thick disk is of particular interest. Because almost all disk galaxies appear to have an old thick disk, thick disks are an important but as yet poorly understood part of the formation process for disk galaxies. Some theories of thick disk formation associate the thick disk with the large star-bursting complexes seen in proto-disk galaxies at high redshift. If the Galactic thick disk was built in this way, from a relatively small number of large aggregates, it will be readily apparent from chemical tagging of the thick disk.

143 – HAD Doggett Prize Lecture: Applied Historical Astronomy
Plenary Session – Potomac Ballroom A – 06 Jan 2014 04:30 pm to 05:20 pm

143.01 – Applied Historical Astronomy

F. Richard Stephenson[1]
1. Durham University, Durham, United Kingdom.

F. Richard Stephenson has spent most of his research career -- spanning more than 45 years -- studying various aspects of Applied Historical Astronomy. The aim of this interdisciplinary subject is the application of historical astronomical records to the investigation of problems in modern astronomy and geophysics. Stephenson has almost exclusively concentrated on pre-telescopic records, especially those preserved from ancient and medieval times -- the earliest reliable observations dating from around 700 BC. The records which have mainly interested him are of eclipses (both solar and lunar), supernovae, sunspots and aurorae, and Halley's Comet. The main sources of early astronomical data are fourfold: records from ancient and medieval East Asia (China, together with Korea and Japan); ancient Babylon; ancient and medieval Europe; and the medieval Arab world. A feature of Stephenson's research is the direct consultation of early astronomical texts in their original language -- either working unaided or with the help of colleagues. He has also developed a variety of techniques to help interpret the various observations. Most pre-telescopic observations are very crude by present-day standards. In addition, early motives for skywatching were more often astrological rather than scientific. Despite these drawbacks, ancient and medieval astronomical records have two remarkable advantages over modern data. Firstly, they can enable the investigation of long-term trends (e.g. in the terrestrial rate of rotation), which in the relatively short period covered by telescopic observations are obscured by short-term fluctuations. Secondly, over the lengthy time-scale which they cover, significant numbers of very rare events (such as Galactic supernovae) were reported, which have few -- if any-- counterparts in the telescopic record. In his various researches, Stephenson has mainly focused his attention on two specific topics. These are: (i) long-term changes in the Earth's rate of rotation -- as revealed by both timed and untimed eclipse observations -- and (ii) historical supernovae. These subjects will form the main theme of his AAS lecture.

144 – AAS Publications Town Hall

Town Hall – Potomac Ballroom C – 06 Jan 2014 06:30 pm to 08:00 pm

The AAS publishing program continues to evolve, and this Town Hall offers the community an opportunity to hear from and interact with the leaders of the program about current issues and concerns as well as new initiatives and future directions.

200 – The Thick and Thin Disks in Spiral Galaxies
Plenary Session – Potomac Ballroom A – 07 Jan 2014 08:30 am to 09:20 am

200.01 – The Thick and Thin Disks in Spiral Galaxies

Rosemary F. Wyse[1]
1. Johns Hopkins Univ., Baltimore, MD, United States.

The vertical structure of stellar disks in spiral galaxies is determined by the relative importances of diverse physical processes, including gaseous dissipation prior to star formation, subsequent gas accretion into the disk, heating mechanisms such as interactions with transient spirals, and the mass ratios and gas content of merging systems. The radial structure reflects star-formation rates, angular momentum (re)distribution (for example, torques during mergers and from non-axisymmetric structures in the disk) and interactions within the disk. The kinematic, chemical and age distributions of the stellar populations of present-day disks, as a function of scale-height and scale-length, provide further constraints on disk evolution. Decomposition of disks into distinct spatial components -- such as thin and thick -- is most meaningful when the spatial decomposition is accompanied by distinct stellar populations and/or different physical processes determining their properties. Direct study of resolved disks at redshifts of around 2 provides complementary information to that from the Milky Way Galaxy and other nearby spirals. I will present my perspective on our current understanding and prospects for the future.

243 – The Cosmic Origins Spectrograph view of the Circumgalactic Medium Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

243.01 – The High-Ion Content and Kinematics of Low-Redshift Lyman Limit Systems

Andrew Fox[1], Nicolas Lehner[2], Jason Tumlinson[1], J. C. Howk[2], Todd M. Tripp[3], Jason X. Prochaska[4], John O'Meara[5], Jessica Werk[4], Rongmon Bordoloi[1], Neal Katz[3], Benjamin Oppenheimer[6, 7], Romeel Dave[8]
1. STScI, Baltimore, MD, United States. 2. University of Notre Dame, Notre Dame, IN, United States. 3. University of Massachusetts, Amherst, MA, United States. 4. UCO/Lick Observatory, Santa Cruz, CA, United States. 5. St Michael's College, Colchester, VT, United States. 6. University of Leiden, Leiden, Netherlands. 7. University of Colorado, Boulder, CO, United States. 8. University of the Western Cape, Bellville, South Africa.

We study the high-ionization phase and kinematics of the circumgalactic medium around low-redshift galaxies in a sample of 23 low-z (0.08<z<0.93) Lyman Limit Systems (LLSs) observed with the Cosmic Origins Spectrograph onboard HST. In Lehner et al. (2013), we recently showed that low-z LLSs have a bimodal metallicity distribution. Here we extend that analysis to search for differences between the high-ion and kinematic properties of the metal-poor and metal-rich branches. We find that metal-rich LLSs tend to show higher O VI columns and broader O VI profiles than metal-poor LLSs. The total H I line width (dv90 statistic) in LLSs is not correlated with metallicity, indicating that the H I kinematics alone cannot be used to distinguish inflow and outflow in LLSs. Among the 17 LLSs with O VI detections, all but two show evidence of kinematic sub-structure, in the form of O VI-H I centroid offsets, multiple components, or both. Using various scenarios for how the metallicity in the high-ion and low-ion phases of each LLS compare, we constrain the ionized hydrogen column in the O VI phase to lie in the range log N(H II)~17.6-20. Therefore, the O VI phase of LLSs traces a substantial baryon reservoir, with M(high-ion)~10^{8.9-10.9}(r/150 kpc)^2 solar masses, similar to the mass in the low-ion phase. Accounting for the O VI phase approximately doubles the contribution of low-z LLSs to the cosmic baryon budget.

243.02 – The First Detection of Deuterated Molecular Hydrogen at z < 1.7 Beyond the Milky Way Galaxy

Cristina M. Oliveira[1], Jason Tumlinson[1], Kenneth Sembach[1], John O'Meara[2], Christopher Thom[1]
1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Saint Michaels College, Colchester, VT, United States.

We report on the first detection of deuterated molecular hydrogen, HD, at a redshift < 1.7 beyond the Milky Way galaxy. HD and H2 are detected in HST/COS data of a low metallicity (Z ~ 0.07Z_sun) damped Lyα system at z = 0.18562 toward QSO B0120-28, with log N(H I) = 20.50 +/- 0.10. Four absorption components are clearly resolved in H2 while two components are resolved in HD; the bulk of the molecular hydrogen is associated with the components traced by HD. We find total column densities log N(HD) = 14.82 +/- 0.15 and log N(H2) = 20.00 +/- 0.10. This system has a high molecular fraction, f(H2) = 0.39 +/- 0.10 and a low HD to H2 ratio, log (HD/2xH2) = -5.5 +/- 0.2 dex. The excitation temperature, T01 = 65 +/- 2 K, in the component containing the bulk of the molecular gas is lower than in other DLAs. These properties are unlike those in other DLA systems but are consistent with what is observed in dense clouds in the Milky Way.

243.03 – The CGM around Dwarf Galaxies

Jason Tumlinson[1], Rongmon Bordoloi[1]
1. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: The COS-Halos Team

This poster will present the first results mapping the 2-D distribution of circumgalactic gas around nearby dwarf galaxies from the COS-Dwarfs survey. COS-Dwarfs uses HST/COS spectroscopy to probe the halos of low redshift galaxies with luminosities L = (0.02 - 0.3)L*, stellar masses (M*) = 10^(8-10) Msun, up to impact parameters of 150 kpc. Using sensitive UV absorption-line measurements of the multiphase gas diagnostics such as Lyα, CII/IV, Si II/III/IV We present the radial and azimuthal distribution of such gas around these galaxies. We also show how the absorption strengths vary with host galaxy color, mass, star formation rate, orientation, and how they compare with that of the L* galaxies probed by our related COS-Halos survey. In particular, I will present the dependence of CIV absorption on specific star formation rate (sSFR) and a total mass estimate for carbon around these dwarf galaxies.

243.04 – Searching for Diffuse Lyα Emission in the Local IGM/CGM with HST/COS

Steven V. Penton[1], James C. Green[2], Charles Danforth[2]
1. STScI, Baltimore, MD, United States. 2. University of Colorado, Boulder, CO, United States.
Contributing teams: HST/COS GTO

The Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope (HST) has observed thousands of Lyman-alpha (Lyα) forest absorbers with both the G130M grating (0< z < 0.19) and the G160M grating (0.14 < z < 0.48). In this research, we use the two-dimensional nature of the COS FUV detector to constrain the Lyα EMISSION associated with both these Lyα absorbers, AND regions of the IGM not associated with Lyα absorbers. We will divide our Lyα absorber sample based upon proximity to the closest known galaxy to differentiate emission between intergalactic (IGM) and circumgalactic (CGM) regions. We will discuss the limits of these constraints/detections in terms of both cosmological implications and from a technological standpoint (If we were to design a Lyα emission detection/mapping mission, what have we learned from HST+COS ?).

243.05 – The Metallicity Distribution of the Circumgalactic Medium at z < 1 Traced by Lyman Limit Systems

Christopher Wotta[1], J. C. Howk[1], Nicolas Lehner[1], John O'Meara[2]
1. University of Notre Dame, Notre Dame, IN, United States. 2. Saint Michael's College, Colchester, VT, United States.

The circumgalactic medium (CGM), the interface between the intergalactic medium and the galaxy halo, harbors flows of galactic infall and outflow that may interact in interesting ways. Studying this cool (T ~ few x 10^4 K) CGM gas will give us insights into the balance and mixing of these flows, and enable us to assess current galaxy evolution models. The typical densities of CGM gas lead to H I column densities characteristic of Lyman limit systems (LLSs). Lehner et al. (2013) showed that the low-redshift LLSs have a bimodal metallicity distribution, with low- and high-metallicity branches centered at ~3% and 40% of the solar metallicity. . However, their sample was dominated by optically thin LLSs [16 < log N(HI) < 17.2]. We present a survey of the metallicity in a sample of 0.25 < z < 1 LLSs selected on the basis of their Lyman break optical depth from a snapshot survey with the Cosmic Origins Spectrograph (COS) on board HST. We combine the H I column densities of these systems with ground-based measurements of Mg II strength from LBT/MODS, Magellan/MagE, and Keck/HIRES observations. We calculate the metallicity using only Mg II lines and a mean ionization correction, rather than a detailed assessment of several metal lines, and assess the reliability of this approach by comparing it to the Lehner et al. method. We use the metallicity estimates to determine what fraction of LLSs [16 < log N(HI) < 18.5] is metal poor, and compare it to the Lehner et al. results and the unimodal distribution of damped Lyman-alpha abundances at these redshifts. We comment on the implications of our measurements for understanding the cold-mode accretion phenomenon.

243.06 – C IV In Our Cosmic Backyard: Which Neighbor Put It There?

Joseph Burchett[1], Joseph Burchett[1], Todd M. Tripp[1], Jessica Werk[2], Jason X. Prochaska[2], Jason Tumlinson[3], J. C. Howk[4]
1. University of Massachusetts - Amherst, Amherst, MA, United States. 2. University of California Observatories - Lick Observatory, Santa Cruz, CA, United States. 3. Space Telescope Science Institute, Baltimore, MD, United States. 4. University of Notre Dame, Notre Dame, IN, United States.

We have identified 40 absorption systems at z < 0.16 through a blind survey for C IV absorbers in HST/COS spectra from 89 QSO sightlines. Our independent analysis, using a larger sample size than previous studies in this redshift range, indicates an increasing C IV absorber number density per comoving path length (dN/dX) and increasing mass density relative to the critical density of the Universe ($?_{C+3}$) from z~0.5 to the present epoch. In addition, we are following up the spectroscopic survey with a survey for associated galaxies using archival data along with new observations to study to the nature of the absorbing gas. We find a surprising number of absorbers that appear to have larger separations from potentially associated galaxies in both impact parameter and/or velocity than have previously been reported. One particular absorber/galaxy association shows characteristics indicative of cold accretion.

244 – Star Formation Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

244.01 – Stellar populations and Star Formation Rates in NGC 6872, the Condor galaxy

Rafael T. Eufrasio[1,2], Duilia F. De Mello[2,1], Eli Dwek[1], Richard G. Arendt[3,1], Dimitri A. Gadotti[4]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 2. The Catholic University of America, Washington, DC, United States. 3. CRESST UMBC, Baltimore, MD, United States. 4. European Southern Observatory, Santiago, Chile.

We present a detailed analysis of the Spectral Energy Distributions (SEDs) of 10 kpc regions across the giant spiral galaxy NGC 6872, the Condor galaxy. We made use of archival data from the FUV (GALEX) to 22 μm (WISE). In order to find any signature of the recent interaction (~130 Myr) with its companion, the S0 galaxy IC 4970, we inspected the SED of Condor's bar. One possibility is that is would have been formed by passage of the companion. We find that it is a particularly long bar (9 kpc semi-major axis), with a size almost twice as large as the average found in other barred galaxies (4.5 kpc median in the local universe, Gadotti 2011). A bulge/bar/disk 2D decomposition using the Spitzer 3.6 μm image and the budda package (de Souza et al. 2004; Gadotti 2008) reveals that the ratio of the bar semi-major axis to the disk scale-length is 1.4, which is a value typically found in other barred galaxies (see Fig. 1 in Gadotti 2011). The disk scale-length is ~ 7 kpc, which is extremely large (2.8 kpc median in local galaxies, Gadotti 2009). Our analysis also shows that there are no signs of recent star formation along the bar. We find no signs of a box-peanut structure near the central regions, which is also another signature of an evolved bar. Taken altogether, the evidence points to a bar formed at least a few billion years ago and the stars in the bar seem to be a fossil record of the stellar population in the galaxy before the interaction with its companion. Then, we modeled the SFH of each 10 kpc region as constant Star Formation Rate (SFR) for the past 100 Myr superposed on an exponentially decaying, longstanding SFR. We find a single exponential SFH to account for all the recent SFR of the galaxy, with no need for an additional SFR due to the interaction. Av is low all across the galaxy (~ 0.25), but increases near (~ 0.7) the point of collision. The SFH of the arms are asymmetric. The northeastern arm having older ages (~ 5 Gyr) and SFH closer to constant, while the southwestern one has much younger age (~ 1.5 Gyr) and SFR closer to a single burst. The derived total stellar mass of each region correlates linearly with the Spitzer 4.5 μm fluxes and non-linearly with the derived bolometric luminosity.

244.02 – High-Mass Star Formation in NGC6822: The Ultraviolet as a Tool for Identification

Anne Hedlund[1,2], Barry F. Madore[2], Bryan E. Penprase[1], Philip I. Choi[1]
1. Pomona College, Claremont, CA, United States. 2. Carnegie Institute of Science, Pasadena, CA, United States.

One of the challenges involved in studying star formation rates is the inability to distinguish cold and hot stars in longer wavelengths of the spectrum. When looking at empirical star formation laws, this uncertainty in star formation tracers makes it difficult to tell whether dispersion in laws such as the Kennicutt-Schmidt law is due to instrumental error or galactic evolutionary differences. By matching Galaxy Evolution Explorer (GALEX) ultraviolet data with a Massey catalog of the U, B, V, R, and I bands for NGC6822, I will be able to examine the spectral energy distributions of stars in this galaxy from the far ultraviolet to the near-infrared. Using the varying luminosities in the ultraviolet part of the spectrum, I will be able to identify young, massive stars such as O and B stars. By comparing these young, massive stars' spatial distribution with gas distributions and H-alpha maps from TYPHOON, I will be able to explore topics related to star formation and star formation laws, such as the dispersion in empirical star formation laws and the possible effects of gas densities, metallicities, and the uncertainties in star formation tracers.

244.03 – New Star Formation in NGC 3690

Ajamu Abdullah[1]
1. Howard University, Washington D.C., DC, United States.

NGC 3690 is a system of merging spiral galaxies located in Ursa Major about 150 million light years away from Earth. A significant burst of star formation has occurred as a result of these merging galaxies. HST observations in the B,I, and far-UV bands reveal active star formation within this pair of luminous infrared galaxies (LIRGs), which are factories of star birth, primary sources of thermal energy emission in the far-infrared spectrum, and characterized by the abundant presence of dust in the interstellar medium. Significant amounts of dust poses as an observation obstacle, and hinders us from seeing processes of star formation inside the merging system at visible wavelengths using optical telescopes. Dust re-emits absorbed starlight (i.e. UV radiation) as thermal infrared emission which can be seen by radio telescopes (the VLA, VLBA, and ALMA to name a few). One of my primary goals is to determine approximate ages of star clusters in the NGC 3690 system, which has had six supernovae within the last fifteen years.

244.04 – Stacking Spectra of High Critical Density Tracers in ALMA Cycle 0 Observations of the Antennae Galaxies

Jennifer Kadowaki[1, 2], Adam K. Leroy[2], Loreto Barcos[3], Cheoljong Lee[3], Bradley C. Whitmore[4], Crystal L. Brogan[2], John E. Hibbard[2], Kelsey E. Johnson[3], Rupali Chandar[5], George C. Privon[3], Aaron S. Evans[2, 3], Anthony J. Remijan[2], Kartik Sheth[2]

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The Antennae galaxies are the nearest major merger. In order to understand star formation in the starbursts induced by such mergers, we mapped molecular line emission from the overlap region in the Antennae galaxies as part of Early Science (``Cycle 0'') with the Atacama Large Millimeter/Submillimeter Array (ALMA). We simultaneously observed the bright molecular gas tracer CO (3-2) and the faint dense gas tracers HCN (4-3) and HCO+ (4-3) at 0.50" (50pc) resolution. Although CO 3-2 was detected throughout the merger, the dense gas tracers were fainter. In this poster we show the results of spectral line stacking to pull out average HCN and HCO+ intensity measurement. We detect averaged emission from both tracers across a wide area, with HCO+ about a factor of two brighter than HCN. Hints of variations in HCN/CO and HCO+/CO ratios suggest the presence of lower dense gas fraction at lower surface densities with the brightest emission about H2 surface densities of ~300 Msun/pc^2 (HCN) and ~60 Msun/pc^2 (HCO+). In addition to providing a powerful probe of where the next generation of stars are forming, this technique demonstrates the immense wealth of science that can be extracted from ALMA data with sophisticated analysis techniques.

244.05 – The Green Bank Telescope Maps the Dense Molecular Gas in the Starburst Galaxy M82

Amanda A. Kepley[1], Adam K. Leroy[2], David T. Frayer[1], Antonio Usero[3], Joshua Marvil[4, 5], Fabian Walter[6]

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In both the Milky Way and nearby galaxies, the presence of dense molecular gas is correlated with recent star formation, suggesting that the formation of this gas may represent a key regulating step in the star formation process. Testing this idea requires wide-area, high-resolution maps of dense molecular gas in galaxies to explore how local physical conditions drive dense gas formation. Until now, these observations have been limited by the faintness of dense gas tracers like HCN and HCO+, but new instruments like the 4mm receiver on Robert C. Byrd Green Bank Telescope (GBT) -- the largest single-dish millimeter telescope -- are poised to change this picture. We present GBT maps of the dense gas tracers HCN and HCO+ in the prototypical nearby starburst galaxy M82. The HCN and HCO+ in the disk of M82 correlates both with recent star formation and the diffuse molecular gas and shows kinematics consistent with a rotating torus. HCO+ emission is also associated with the outflow of molecular gas previously identified in CO. These observations mark the first time that dense molecular gas like HCO+ has been associated with an outflow in a nearby galaxy and suggests that the outflow of dense molecular gas from the center of galaxies like M82 may regulate the star formation globally. Finally, the CO-to-HCN and CO-to-HCO+ line ratios reveal that there is more dense gas at the center of M82, pointing to the starburst as a key driver of this relationship. These results establish that the GBT can efficiently map the dense molecular gas at 90 GHz in nearby galaxies; this capability will increase further with the 16-element feed array currently being built for the GBT.

244.06 – Modeling the Star Formation Properties of Massive Galaxies with the COLD GASS Survey

Erica Hopkins[1, 2], Rahul Shetty[2], Frank Bigiel[2], Ralf Klessen[2], Amelie Saintonge[3], Beth Willman[1]

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We investigate the star formation properties of nearby galaxies from the COLD GASS survey. The COLD GASS survey includes IRAM and Arecibo observations of the CO (J=1-0) and HI lines, complemented with optical and UV photometry from SDSS and GALEX, respectively, of 350 massive galaxies (Saintonge et al. 2011). To understand the star formation properties, we consider simple models relating the stellar masses, molecular gas masses, and the star formation rates (SFR), such as the

Kennicutt-Schmidt (KS) relationship. Of particular interest is the gas depletion time (t_{dep}) - specific SFR (sSFR) relationship. Due to the degeneracy in t_{dep} and sSFR, accurately quantifying their relationship requires a rigorous assessment of observational uncertainties. We employ Monte Carlo simulations to thoroughly explore the effect of noise on the estimated parameters. Results suggest that multiple sublinear KS relationships can recover the observed trends, provided a weak dependence of the stellar mass with molecular content.

244.07 – 13CO Survey of Northern Intermediate-Mass Star-Forming Regions

Michael J. Lundquist[1], Henry A. Kobulnicky[1], Charles R. Kerton[2]
1. University of Wyoming, Laramie, WY, United States. 2. Iowa State University, Ames, IA, United States.

We conducted a survey of 13CO with the OSO 20-m telescope toward 68 intermediate-mass star-forming regions (IM SFRs) visible in the northern hemisphere. These regions have mostly been excluded from previous CO surveys and were selected from IRAS colors that specify cool dust and large PAH contribution. These regions are known to host stars up to, but not exceeding, about 8 solar masses. We detect 13CO in 57 of the 68 IM SFRs down to a typical RMS of ~50 mK. We present kinematic distances, minimum column densities, and minimum masses for these IM SFRs.

244.08 – MYSTIX: AGE GRADIENTS IN STELLAR POPULATIONS OF MASSIVE STAR FORMING REGIONS BASED ON A NEW STELLAR CHRONOMETER

Konstantin V. Getman[1], Eric Feigelson[1], Michael A. Kuhn[1], Patrick S. Broos[1], Leisa K. Townsley[1], Tim Naylor[2], Matthew S. Povich[3], Kevin Luhman[1], Gordon Garmire[4]
1. Pennsylvania State University, University Park, PA, United States. 2. University of Exeter, Exeter, Devon, United Kingdom. 3. California State Polytechnic University, Pomona, CA, United States. 4. Huntingdon Institute for X-ray Astronomy, Huntingdon, PA, United States.

The MYStIX (Massive Young Star-Forming Complex Study in Infrared and X-ray, Feigelson et al. 2013) project characterizes 20 OB-dominated massive star forming regions (MSFRs) at distances <4 kpc using photometric X-ray, NIR, and MIR catalogues. As part of MYStIX, we developed a new stellar chronometer that employs NIR and X-ray data, AgeJX. The method is sensitive to wide stages of evolution, from embedded in a cloud disk-bearing stars to widely dispersed older pre-main sequence stars. AgeJX has been applied to >5500 out of >31000 MYStIX Probable Complex Members. To overcome the dispersion of highly uncertain individual ages, we report median ages of stellar samples within (sub)clusters that are spatially discriminated by Kuhn et al. (2013). The important science result is the discovery of age gradients across MYStIX regions as well as within some individual rich clusters. We find narrowly constrained ages in these spatially distinct structures. Spatial gradients in median age values are often seen consistent with astronomically reasonable patterns of star formation histories, with older lightly absorbed structures on one side, younger heavily absorbed structures on the other side, and intermediate-age structures in the middle. Widely distributed populations are nearly always have older ages than the principle clusters. The progression of star formation within a MSFR can be traced over spatial scales of several parsecs and time scales of several million years. We provide a homogeneous set of averaged AgeJX for >130 MYStIX (sub)clusters and regions of interest, so patterns of star formation histories can be compared between MSFRs. In addition we report age gradients within the NGC 2024 and Orion Nebula clusters with implications for cluster formation astrophysics.

244.09 – MYSTIX: THE STRUCTURE AND DYNAMICAL STATE OF YOUNG STELLAR CLUSTERS

Michael A. Kuhn[1], Eric Feigelson[1], Konstantin V. Getman[1], Adrian Baddeley[2], Leisa K. Townsley[1], Patrick S. Broos[1], Matthew S. Povich[3], Kevin Luhman[1], Heather Busk[1], Tim Naylor[4], Robert King[4]
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MYStIX (Massive Young Star-Forming Complex Study in Infrared and X-ray; Feigelson et al. 2013) is a recent survey of star-forming regions (d<4 kpc) in the X-ray and infrared, revealing >30,000 young stellar complex members. Overall, ~150 subclusters of young stars are found (1 to >10 per region) using a statistical cluster finding algorithm -- the finite mixture model. The spatial arrangments of clusters in different regions can be divided into four classes -- simple, isolated clusters, clusters with a core-halo structure, clumpy clusters, and linear chains of clusters. Clusters are often projected on or near molecular-cloud clumps or cores, particularly in the latter morphological case where subclusters are often located along cloud filamentary structures. Subluster size is negatively correlated with cluster central density (power-law with index slightly shallower than -3) and with gas/dust absorption; both of which may be explained as an effect of subcluster expansion. Overall, star formation appears to be non-coeval in the MYStIX regions, due to the wide range of subcluster properties within individual regions.

244.10 – Outflow-protostar interactions in the Serpens South Cluster

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Crowded, stellar cluster-forming regions should result in interactions between outflows from young stars and nearby cluster members. These interactions will play an important role in the mass accretion of cluster members, and thus influence the evolution of young stellar objects in the cluster. We present molecular line and dust continuum observations of the dense, young star-forming cluster Serpens South which show clear evidence for the interaction between a jet-like outflow and a nearby young star.

244.11 – The Structure of Dense Gas in Perseus and Serpens: CLASSy Results

Lee G. Mundy[1], Shaye Storm[1], Manuel Fernandez Lopez[2], Katherine Lee[1,2], Leslie Looney[2], Peter J. Teuben[1], Erik Rosolowsky[3], Yancy L. Shirley[4], Hector G. Arce[5], Adele Plunkett[5], Andrea Isella[6]
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Contributing teams: CLASSy Team

We present results of a dendrogram analysis of N2H+ J=1-0 data cubes from the CARMA Large Area Star-formation Survey (CLASSy). Dendrogram tree structures are characterized by their morphology and kinematics relative to one another, and provide a useful mechanism for analyzing the hierarchy of molecular regions from core-to-cloud spatial scales. Our CARMA data, with 7" spatial and 0.15 km/sec velocity resolution, yield the following results: (1) trees are more hierarchical in regions of high star formation activity; (2) in all regions, the leaf and branch morphology is widely varying and mostly not circularly symmetric; (3) there is evidence for multiple velocity components along a line of sight in only a small fraction of the mapped areas. We compare the identified N2H+ dendrogram tree structures to Herschel maps of dust emission and to Spitzer-identified young stellar object distributions to compare the dense gas distribution to the current star formation activity.

244.12 – Analysis of the Serpens South Filamentary Cloud: CLASSy Results

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Contributing teams: CLASSy Team

We present a study of the Serpens South cloud, which is part of the CARMA Large Area Star-formation Survey (CLASSy) project. We observed a 210 square arcminute area of the Serpens South region, mapped at 7? resolution using the CARMA 23-dish mode in the HCN, HCO^+, and N_2H^+ J=1-0 emission lines. The CARMA 23-dish mode combines simultaneous interferometric data from the 3.5 m, 6.1 m, and 10 m antennas and autocorrelation spectra from the 10-m antennas to reconstruct full spatial images of the molecular emission lines, tracing the structures from the large to small scales to better understand how clouds evolve to form stars. Serpens South is thought to be a very young star-forming region (a few 10^5 yr) with a central cluster of protostars lying at the origin of a radial filamentary structure. The CLASSy images allow us to analyze in detail the spatial structure and gas kinematics of the central hub and the substructure of the filaments. The northern ~1 pc filament is clearly resolved into a more collimated strips of gas. Its connection with the central hub is not physically as clear as the connection of the southwestern and southeast filaments. These filaments are also resolved into several collimated structures, many of which are also velocity separated given the high-spectral resolution of the CLASSy data (0.15 km/s).

244.13 – Infall as a Function of Position and Molecular Tracer in L1544 and L694

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The standard model of core collapse suggests that this process works from the inside and moves outwards, with the fastest motions at the center. The relative abundances of many molecules also vary within cores, with certain molecules found only in specific regions characterized by narrow ranges of temperature and density. These characteristics lead to the hypothesis that the observed infall speeds in starless cores depend on both the position of the observations and the molecular tracer chosen. Although surveys of infall motions in dense cores have been carried out for years, very few surveys have been awarded enough time to map infall across cores using multiple spectral line observations. To fill this gap, we present IRAM 30m maps of N_2H^+(1-0), DCO^+(2-1), DCO^+(3-2) and HCO^+(3-2) towards two prestellar cores (L1544 and L694). We find that the measured infall velocity varies as a function of position across each core and varies with the choice of molecular line, likely as a result of radial variations in core chemistry and dynamics.

244.14 – An accretion disks in the high-mass star forming region IRAS~23151+5912.

Victor Migenes[1], Tatiana Rodríguez-Esnard[2], Miguel A. Trinidad[3]
1. Brigham Young University, Provo, UT, United States. 2. Instituto de Geofísica y Astronomía, La Havana, Havana, Cuba. 3. University of Guanajuato, Guanajuato, Guanajuato, Mexico.

We present observations of radio continuum emission at 1.3 and 3.6 cm and H2O masers toward the high-mass star-forming regions IRAS~23151+5912 carried out with the VLA-EVLA. We detected one continuum source at 1.3 cm and 13 water maser spots which are distributed in three groups aligned along the northeast-southwest direction. Our results suggest that the 1.3 cm emission is consistent with an HC HII region, probably with an embedded zero-age main sequence star of type B2. In particular, we find that this radio continuum source is probably associated with a circumstellar disk of about 680~AU, as traced by water masers. Furthermore, the masers of the second group are probably describing another circumstellar disk of about 86 AU, whose central protostar is still undetected. We discuss this results in the light of more recent high-resolution observations.

244.15 – Stellar and Circumstellar Properties of Low-Mass, Young, Subarcsecond Binaries

Sara Bruhns[1,2], Lisa A. Prato[1]
1. Lowell Observatory, Flagstaff, AZ, United States. 2. University of Virginia, Charlottesville, VA, United States.

We present a study of the stellar and circumstellar characteristics of close (< 1''), young (< 2 to 3 Myr), low-mass (<1 solar mass) binary stars in the Taurus star forming region. Low-resolution (R ~ 2000) spectra were taken in the K-band using adaptive optics to separate the observations for each component and identify the individual spectral types, extinction, and K-band excess. Combining these data with stellar luminosities allows us to estimate the stellar masses and ages. We also measured equivalent widths of the hydrogen Brackett gamma line in order to estimate the strength of gas accretion. We obtained spectra for six binary systems with separations from 1'' down to 0.3''. In the CZ Tau binary we found that the fainter secondary star spectrum appears to be of earlier spectral type than the primary; we speculate on the origin of this inversion.

244.16 – You Can Touch This! Bringing HST images to life as 3-D models

Carol A. Christian[1], Antonella Nota[1], Noreen A. Grice[3], Elena Sabbi[1], Natalie Shaheen[2], Perry Greenfield[1], Amy Hurst[5], Shaun Kane[5], Roshan Rao[6], Josh Dutterer[5], Selma E. de Mink[4]
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We present the very first results of an innovative process to transform Hubble images into tactile 3-D models of astronomical objects. We have created a very new, unique tool for understanding astronomical phenomena, especially designed to make astronomy accessible to visually impaired children and adults. From the multicolor images of stellar clusters, we construct 3-D computer models that are digitally sliced into layers, each featuring touchable patterning and Braille characters, and are printed on a 3-D printer. The slices are then fitted together, so that the user can explore the structure of the cluster environment with their fingertips, slice-by-slice, analogous to a visual fly-through. Students will be able to identify and spatially locate the different components of these complex astronomical objects, namely gas, dust and stars, and will learn about the formation and composition of stellar clusters. The primary audiences for the 3D models are middle school and high

school blind students and, secondarily, blind adults. However, we believe that the final materials will address a broad range of individuals with varied and multi-sensory learning styles, and will be interesting and visually appealing to the public at large.

244.17 – The First Stars: A Low-Mass Formation Mode

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We perform numerical simulations of the growth of a Population III stellar system under photodissociating feedback. We start from cosmological initial conditions at z=100, self-consistently following the formation of a minihalo at z=15 and the subsequent collapse of its central gas to high densities. The simulations resolve scales as small as ~ 1 AU, corresponding to gas densities of 10^16 cm^-3. Using sink particles to represent the growing protostars, we evolve the stellar system for the next 5000 years. We find that this emerging stellar group accretes at an unusually low rate compared with minihalos which form at earlier times (z=20-30), or with lower baryonic angular momentum. The stars in this unusual system will likely reach masses ranging from < 1 M_sol to ~ 5 M_sol by the end of their main-sequence lifetimes, placing them in the mass range for which stars will undergo an asymptotic giant branch (AGB) phase. Based upon the simulation, we predict the existence of Population~III stars that have survived to the present day and have been enriched by mass overflow from a previous AGB companion.

244.18 – Stringent Limits of O2 Abundance Toward a Low-mass Protostar with Herschel-HIFI

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Contributing teams: HOP (Herschel Oxygen Project) Team

Even though molecular oxygen (O2) has a simple chemical structure, it remains difficult to detect in the interstellar medium after many years of searches. According to traditional gas-phase chemical models, molecular oxygen O2 should be abundant in molecular clouds (X(O2)~7e-5 relative to H2), but until recently, attempts to detect interstellar O2 line emission with ground- and space-based observatories have failed. Following the multi-line detection of O2 with low abundances in the Orion and rho OphA molecular clouds with Herschel, it is important to investigate other environments, and we here quantify the O2 abundance near a solar-mass protostar for the first time. Observations of molecular oxygen, O2, at 487 GHz toward a deeply embedded low-mass Class 0 protostar, NGC 1333 IRAS 4A, are presented, using the HIFI on the Herschel Space Observatory. The high spectral resolution data are analyzed using radiative transfer models to infer column densities and abundances, and are tested directly against full gas-grain chemical models. The deep HIFI spectrum (rms=1.3 mK) fails to show O2 at the velocity of the dense protostellar envelope, implying one of the deepest abundance upper limits of O2/H2 at <6x10e-9 (3 sigma). The O2/CO abundance ratio is less than 0.005. However, a tentative (4.5 sigma) detection of O2 is seen at the velocity of the surrounding NGC~1333 cloud, shifted by 1 km/s relative to the protostar. Pure gas-phase models and gas-grain chemical models require a long pre-collapse phase (~0.7-1x10e6 years) during which atomic and molecular oxygen are frozen out onto dust grains and fully converted to H2O to avoid overproduction of O2 in the dense envelope. The tentative detection of O2 in the surrounding cloud is consistent with a low-density PDR model with a small enhancement of the water-ice photodesorption yield of a factor of two. The low O2 abundance in the collapsing envelope around a low-mass protostar suggests that the gas and ice entering protoplanetary disks is very poor in O2. This research is described in Yildiz et al. (2013, A&A, astro-ph: 1307.8031).

244.19 – Using Class 0/I Protostars to Study Triggered Star Formation in NGC 281 with Herschel Photometry

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Contributing teams: NITARP

Mid- and far-infrared 24, 70, 100, 160 μm images from the Herschel and Spitzer Space Observatories were examined in an effort to understand the mechanisms at work in the star-forming region NGC 281. Two different populations of protostars exist in the region: those within a large molecular cloud obscured by dust (NGC 281 West) and those associated with filamentary pillars and triggered star formation (NGC 281 East). Color-color diagrams were utilized to identify specific

classes of Class 0/I protostars in each distinct half of the nebula. In addition, spatial and/or flux distributions of protostars were produced to reveal any contrasting mode of star formation at work in each of the two separate regions.

244.20 – A Numerical Simulation of Star Formation in Nuclear Rings of Barred-Spiral Galaxies.

Woo-Young Seo[1], Woong-Tae Kim[1]
1. Seoul National University, Seoul, Korea, Republic of.

We use grid-based hydrodynamic simulations to study star formation history in nuclear rings of barred-spiral galaxies. We assume infinitesimally thin, isothermal, and unmagnetized gaseous disk. To investigate effects of spiral arm potential, we calculate both models with and without spiral. We find that star formation rate (SFR) in a nuclear ring is determined by the mass inflow rate to the ring rather than the total gas mass in the ring. In case of models without spiral arms, the SFR shows a strong primary burst at early time, and declines to small values after after that. The primary burst is caused by the rapid gas infall to the ring due to the bar growth. On the other hand, models with spiral arms show multiple star bursts at late time caused by additional gas inflow from outside bar region. When the SFR is low, ages of young star clusters exhibit a bipolar azimuthal gradient along the ring since star formation occurs near the contact points between dust lanes and the nuclear ring. When the SFR is large, there are no age gradient of star clusters since star formation sites are widely distributed throughout the whole ring region.

244.21 – ALMA observations of the extremely high velocity, massive and compact molecular outflow G331.512-0.103.

Manuel Merello[1], Neal J. Evans [1], Leonardo Bronfman[2], Guido Garay[2], Nadia Lo[2], Lars-Ake Nyman[3], Juan R. Cortés[3], Maria R. Cunningham[4]
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Cycle 0 ALMA observations are presented for one of the most energetic and luminous molecular outflows known in the Galaxy, G331.512-0.103. High angular resolution observations with Band 7 (350 GHz; 0.86 mm) show that the bipolar molecular outflow is very compact and extremely young, with velocities relative to the ambient cloud of 70 km/s. The SiO (8-7) emission is confined in a region less than 5'' in size, corresponding to 0.18 pc at the source distance 7.5 kpc, and it reveals the presence of a ring-type structure toward the systemic velocity of the source. This feature is also observed in the $H13CO+$ emission line, and the cavity is coincident with a strong and compact radio continuum source detected at 4.8 and 8.6 GHz, using ATCA. We interpret these observations as a young stellar object producing a compact H II region, with an expansion shock propagating into the medium and possible dense material still infalling around this shell. The expansion velocity of the shocked shell is ~ 24 km/s, suggesting a crossing time of about 2000 yr. The spectral index of the radio continuum source is consistent with an ionized jet, which is likely to drive the associated energetic molecular outflow. The $H13CO+$ emission also shows the presence of a feature in the position-velocity maps, associated with the presence of a bullet of dense material. The complete Band 7 spectra show a rich set of complex emission lines, possibly associated with hot core chemistry, with gas rotational temperature ~ 100 K. The source is one of the youngest examples of a massive molecular outflow found associated with a high-mass star.

245 – Cosmology Poster Session
Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

245.01 – Challenges of Measuring Cosmic Dawn with the 21-cm Sky-Averaged, Global Signal

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The sky-averaged 21-cm signal is perhaps the most promising near-term probe of the "Cosmic Dawn", when the first stars and galaxies began to heat and ionize the Universe. Measurements are still challenging, however, because of the intense foregrounds at the relevant low radio frequencies, the exquisite instrumental calibration this necessitates, human-generated radio frequency interference (RFI), and the Earth's ionosphere. The latter three problems can be mitigated by studying the Cosmic Dawn from the farside of the Moon. The proposed Dark Ages Radio Explorer (DARE) would do so by carrying a dipole antenna to in a low lunar orbit. We outline this mission, show the constraints it can put on the physics of the cosmic dawn, and demonstrate how the ionosphere puts a fundamental limit on the sensitivity of similar, ground-based experiments.

245.02 – Multiple Deflections in Galaxy-Galaxy Lensing

Kelly Blumenthal[1], Tereasa G. Brainerd[1]
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Galaxy-galaxy lensing arises when background galaxies are lensed systematically by foreground galaxies. This occurs in the weak lensing regime, resulting in shears of order 0.1% or less. Therefore, accurate observational detection of galaxy-galaxy lensing requires a large ensemble of galaxies, resulting in hundreds of thousands to millions of galaxy pairs. Observations of galaxy-galaxy lensing have been used to place direct constraints on the nature of the dark matter halos that surround the lens galaxies and have yielded a picture of luminous galaxies and their halos that is generally consistent with the expectations of Cold Dark Matter. Galaxies span a wide range in masses and are broadly distributed in redshift space. Because of this, the lensing galaxy with the smallest impact parameter may not be the only galaxy that lenses a given source, and it may not even be the strongest lens for the source. That is, the net shear for a given source may be the result of multiple weak deflections due to more than one weak galaxy lens. Previous theoretical studies of typical deep galaxy-galaxy lensing data sets have shown that almost all source galaxies have been weakly lensed by three or more foreground galaxies. These multiple deflections due to independent weak galaxy lenses do not cancel out and, in general, they result in a greater net shear for a given source than the shear from the single closest lens. Here we use a set of simulations to investigate the effects of multiple deflections in galaxy-galaxy lensing, approximating the lens galaxies as single isothermal spheres. We use a fixed plane of sources in redshift space, and we systematically vary the masses and the redshift distributions of the lenses. We quantify the frequency with which multiple deflections occur, and we determine the effects of multiple deflections on the net tangential shear. Further, we compare the net tangential shear and to the mean surface mass density of the lens galaxies. This then allows us to compare the actual mean excess surface mass density, ? ?, to the theoretical expectation that ? ? = ?$_t$?$_c$.

245.03 – Foreground Cleaning for Primordial Gravitational Wave Detection

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Contributing teams: CLASS Collaboration

By searching for B-modes in the CMB, the Cosmology Large Angular Scale Surveyor (CLASS) will make polarization measurements that will constrain theories of cosmological inflation. CLASS will measure the CMB at low multipole moments to avoid contamination by gravitational lensing from extragalactic clusters. In order to measure the CMB on large angular scales, we have to accurately subtract foreground emission from the Milky Way in the form of synchrotron and thermal dust emission. Using characteristic sensitivities of the CLASS instrument, we create cosmological simulations and make simulations of the sky at 40 GHz, 90 GHz, and 270 GHz. Using a simple pixel-based likelihood calculation, we extract the tensor-to-scalar ratio r to values as low as 0.01.

245.04 – An Exposition on Friedmann Cosmologies with Negative Energy Densities

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How would negative energy density affect a classic Friedmann cosmology? Although never measured and possibly unphysical, the evolution of a universe containing a significant cosmological abundance of any of a number of hypothetical stable negative energy components is explored. These negative energy (Omega < 0) forms include negative phantom energy

(w < -1), negative cosmological constant (w = -1), negative domain walls (w = -2/3), negative cosmic strings (w = -1/3), negative mass (w = 0), negative radiation (w = 1/3), and negative ultralight (w > 1/3). Assuming that such universe components generate pressures as perfect fluids, the attractive or repulsive nature of each negative energy component is reviewed. The Friedmann equations can only be balanced when negative energies are coupled to a greater magnitude of positive energy or positive curvature, and minimal cases of both of these are reviewed. The future and fate of such universes in terms of curvature, temperature, acceleration, and energy density are reviewed including endings categorized as a "Big Crunch", "Big Void", or "Big Rip" and further qualified with "Warped", "Curved", or "Flat"; "Hot", "Warm" or "Cold"; and "Accelerating", "Coasting", or "Decelerating". A universe that ends by contracting to zero size with zero energy density is termed a "Big Poof". Which contracting Friedmann universes "bounce" in expansion and which expanding universes "turnover" into contraction are also reviewed.

245.05 – Probing Primordial Magnetic Fields with 21-cm Line Observations of the High-redshift Intergalactic Medium

Antonija Oklopcic[1], Vera Gluscevic[2], Christopher M. Hirata[3], Abhilash Mishra[1], Tejaswi N. Venumadhav[1]
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Coherent magnetic fields with strengths of the order of 10^(-5) G are observed on scales of individual galaxies, including the Milky Way. They are thought to be organized and maintained by a dynamo mechanism. However, the nature and origin of the seed magnetic field, required for the dynamo effect to take place, are still unknown. Here, we propose a method of probing the magnetic field in the intergalactic medium before the Epoch of Reionization through observations of redshifted 21-cm radiation of neutral hydrogen. The 21-cm line is created during the spin-flip transition between the hyperfine levels of the hydrogen ground state. The upper hyperfine level is a triplet consisting of atomic states with three different projections of the total angular momentum vector. Anisotropic 21-cm radiation, resulting from perturbations in the high-redshift IGM, unevenly populates triplet sublevels. If an atom is located in an external magnetic field, it precesses between the three states; this causes an additional anisotropy in the 21-cm radiation, which could be imprinted in the 21-cm power spectrum. In order to evaluate the effect of the magnetic field, we need to consider in full detail all mechanisms that affect the distribution of atoms in hyperfine sublevels, such as the interaction of hydrogen atoms with the 21-cm radiation, optical pumping by Lyman-alpha photons, and spin-exchange in hydrogen-hydrogen collisions. Preliminary calculations suggest that this method could be sensitive to extremely weak magnetic fields, of the order of 10^(-17) G.

245.06 – Intergalactic Dust and the Darkness of the Night Sky

Nathan Prins[1], James Overduin[2], Edward J. Strobach[1]
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The intensity of the extragalactic background light (EBL) at optical wavelengths is determined to order of magnitude by the age of the Universe, and reduced by a factor of two due to cosmic expansion. Observations have now attained sufficient precision that we can begin to assess the importance of other factors as well. One of these is absorption in the intergalactic medium, originally proposed by de Cheseaux and Olbers as the entire explanation for the darkness of the night sky. While this explanation fails in a bolometric sense, it does play a role in the spectral sense since dust shifts much of the light from distant galaxies into the infrared. We quantify this effect and show that it reduces the intensity of the optical EBL further by one or two percent. Thus, while Olbers and de Cheseaux had it wrong, they were not quite as wrong as commonly supposed.

245.07 – Comparing the clustering of galaxies and galaxy group by using the SDSS DR7

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By using the angular two-point correlation function, we measure the clustering strength of a clean sample of galaxies (explored in Wang, Brunner, & Dolence 2013) for the Sloan Digital Sky Survey Data Release Seven. By using these same data, we first find isolated pairs, triplets, quads, and larger groups of galaxies, and subsequently measure the clustering of these subsamples. We find the clustering strength increases with groups size, which supports the halo model of galaxy clustering and demonstrates the efficacy of our isolated group catalog for general studies such as the galaxy merger rate. Finally, we explore the effects of galaxy spectral type and photometric redshift on the clustering behavior of these galaxy group samples.

245.08 – Detecting the Relative Velocity Effect with SDSS

Zachary Slepian[1], Daniel Eisenstein[1]

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Before the Universe became neutral (z~1000), baryons were unable to participate in gravitational infall and instead underwent acoustic oscillations. Meanwhile, dark matter perturbations grew via infall. Hence at decoupling (z~1020) there is a significant relative velocity between baryons and dark matter, coherent on scales ~100 Mpc. This is expected to modulate the subsequent formation of galaxies and consequently bias estimates of the baryon acoustic peak today. We present a novel method for detecting the relative velocity effect's signature using 2 and 3 point functions in configuration space, and discuss preliminary results.

245.09 – Updates to the Union SNe Ia Compilation

David Rubin[1, 3], Gregory S. Aldering[3], Rahman Amanullah[4], Kyle H. Barbary[3, 10], Adam Bruce[2], Kyle S. Dawson[7], Susana E. Deustua[5], Mamoru Doi[6], Hannah Fakhouri[2, 3], Andrew S. Fruchter[5], Rachel A. Gibbons[11], Ariel Goobar[4], Eric Hsiao[13, 3], Xiaosheng Huang[14, 3], Yutaka Ihara[6], Alex G. Kim[3], Robert A. Knop[12, 11], Marek Kowalski[15], Evan Krechmer[2], Chris Lidman[16], Eric Linder[3], Joshua Meyers[2, 8], Tomoki Morokuma[6], Jakob Nordin[3], Saul Perlmutter[3, 2], Pascal Ripoche[3], Eli S. Rykoff[3, 9], Clare Saunders[3], Caroline Sofiatti[2, 3], Anthony L. Spadafora[3], Nao Suzuki[6], Naohiro Takanashi[6], Naoki Yasuda[6]

1. Florida State University, Tallahassee, FL, United States. 2. UC Berkeley, Berkeley, CA, United States. 3. LBNL, Berkeley, CA, United States. 4. Stockholm University, Stockholm, Sweden. 5. STScI, Baltimore, MD, United States. 6. University of Tokyo, Tokyo, Japan. 7. University of Utah, Salt Lake City, UT, United States. 8. Stanford, Stanford, CA, United States. 9. SLAC, Menlo Park, CA, United States. 10. Argonne, Lemont, IL, United States. 11. Vanderbilt University, Nashville, TN, United States. 12. Quest University, Squamish, BC, Canada. 13. Las Campanas Observatory, Atacama, Chile. 14. University of San Francisco, San Francisco, CA, United States. 15. University of Bonn, Bonn, Germany. 16. Australian Astronomical Observatory, Marsfield, NSW, Australia. Contributing teams: Supernova Cosmology Project

High-redshift supernovae observed with the Hubble Space Telescope (HST) are crucial for constraining any time variation of dark energy. In a forthcoming paper (Rubin et al., in prep), we will present a cosmological analysis incorporating an updated sample of these supernovae with updated photometry. We also present improved calibrations for the HST ACS and NICMOS cameras.

245.10 – Measuring the Cosmic Distance Scale to 1% with Baryon Acoustic Oscillations in the Sloan Digital Sky Survey III Galaxy Clustering

Daniel Eisenstein[1], Florian Beutler[2], Adam S. Bolton[5], Angela Burden[3], Chia-Hsun Chuang[4], Kyle S. Dawson[5], James E. Gunn[6], Shirley Ho[7], Marc Manera[3], Cameron McBride[1], Olga Mena[8], Francesco Montesano[9], Sebastian Nuza[10], Nikhil Padmanabhan[11], William Percival[3], Beth A. Reid[2], Ashley Ross[3], Nicholas Ross[2, 12], Lado Samushi[3, 13], Ariel Sanchez[9], David J. Schlegel[2], Hee-Jong Seo[14, 15], Jeremy Tinker[16], Mariana Vargas-Magana[7], Martin White[2, 14], David H. Weinberg[15]

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We present the cosmic distance scale as measured from the detection of the baryon acoustic oscillations (BAO) in the clustering of galaxies from the SDSS-III Baryon Oscillation Spectroscopic Survey (BOSS). Our analysis of the Data Release 11 sample uses 1.15 million massive galaxies with spectroscopic redshifts spanning redshift 0.15 to 0.70 and covering 8500 square degrees. We find strong detections of the acoustic peak signature in two redshift bins centered at z=0.32 and z=0.57; in the upper redshift, the detection significance exceeds 8-sigma. These detections produce a robust measurement of the

cosmic distance scale at these redshifts, including a 1% measurement of the distance to z=0.57. We discuss the cosmological implications of the measurements, including combinations with cosmic microwave background anisotropy data sets.

245.11 – Kinematic Weak Lensing: Forecasts for a Next-Generation Lensing Measurement

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Weak gravitational lensing by cosmic structure is a major science driver for several large ongoing and planned imaging surveys, such as the Dark Energy Survey and the Euclid space mission. Traditionally, lensing in this regime is measured via statistical distortions to the shapes of galaxies. While the cosmological constraining power for a large imaging survey employing this technique is great, the signal itself is noisy, and susceptible to a number of systematic biases. Here we propose a new lensing technique that makes use of the kinematics of disk galaxies and the Tully-Fisher relation. Our method controls for that part of the shape noise which arises from the random orientation of galaxy disks, and promises an increase in signal-to-noise sufficient to bring weak lensing measurements within the reach of the next generation of spectroscopic surveys. We define such a survey here, discuss the advantages and disadvantages, and show that the cosmological constraining power of this kinematic weak lensing method is competitive with the most powerful planned lensing measurements.

245.12 – Simulations of 21-cm Intensity Mapping Observations of Baryon Acoustic Oscillations

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Contributing teams: Tianlai Project

Several short baseline radio interferometers are being designed to observe baryon acoustic oscillations (BAO) in the large scale structure of the universe . The arrays observe the 21-cm hyperfine transition line produced by neutral hydrogen in the redshift range of $0.5 < z < 3$. The science goal is to measure the accelerated expansion of the universe by using BAO wiggles as standard rulers. One such instrument is Tianlai, a short baseline radio array currently being designed to operate in a radio-quiet zone in China. Using NRAO's radio interferometry data reduction and analysis software, CASA, proposed Tianlai array configurations were tested for their ability to recover the BAO wiggles from a simulated sky model. To determine the optimal interferometer configuration for BAO observations, various array parameters were optimized, including: antenna latitudinal and longitudinal separation, antenna radius, and array shape.

245.13 – Simulating a Non-Gaussian CMB Sky

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The temperature anisotropies in the Cosmic Microwave Background (CMB) contain imprints of density fluctuations at the time of last scattering. Unavoidable experimental effects, such as sky cuts and inhomogeneous noise, limit observational CMB surveys. To understand these potential constraints on inflationary studies, we generate simulated CMB maps, including those with input parameters based on observational data from the Planck satellite. For the cosmological parameters corresponding to a given CMB bispectrum (the Fourier transform of the three-point correlation function), we use HEALPix subroutines to simulate the CMB with some level of non-Gaussianity in the primordial density field. In order to do this, we implement algorithms to generate non-Gaussian a_{lm}s, corresponding to deviations between temperature fluctuations at different locations. We extend our simulations beyond specific models, such as the local, equilateral, and orthogonal shapes, to general bispectra. By studying bispectra which may not necessarily correspond to any of these well-studied shapes, this more conservative approach avoids making assumptions about the underlying inflationary model, so as to use the data itself to probe potential non-Gaussianity and distinguish among different models and mechanisms of inflation.

245.14 – Variable-delay Polarization Modulators for the CLASS Telescope

Kathleen Harrington[1], Aamir Ali[1], Mandana Amiri[6], John W. Appel[1], Derek Araujo[7], Charles L. Bennett[1], Fletcher Boone[1], Manwei Chan[1], Hsiao-Mei Cho[3], David T. Chuss[2], Felipe Colazo[2], Erik Crowe[2], Kevin Denis[2], Rolando Dünner[4], Joseph Eimer[1], Thomas Essinger-Hileman[1], Dominik

Gothe[1], Mark Halpern[6], Gene Hilton[3], Gary F. Hinshaw[6], Caroline Huang[1], Kent Irwin[3], Glenn Jones[7], John Karakla[1], Alan J. Kogut[2], David Larson[1], Michele Limon[7], Lindsay Lowry[1], Tobias Marriage[1], Nicholas Mehrle[1], Amber D. Miller[7], Nathan Miller[2], Paul Mirel[2], Samuel H. Moseley[2], Giles Novak[8], Carl Reintsema[3], Karwan Rostem[2], Thomas Stevenson[2], Deborah Towner[2], Kongpop U-Yen[2], Emily Wagner[1], Duncan Watts[1], Edward Wollack[2], Zhilei Xu[1], Lingzhen Zeng[5]
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The challenges of measuring faint polarized signals at microwave wavelengths have motivated the development of rapid polarization modulators. One scalable technique, called a Variable-delay Polarization Modulator (VPM), consists of a stationary wire array in front of a movable mirror. The mirror motion creates a changing phase difference between the polarization modes parallel and orthogonal to the wire array. The Cosmology Large Angular Scale Surveyor (CLASS) will use a VPM as the first optical element in a telescope array that will search for the signature of inflation through the "B-mode" pattern in the polarization of the cosmic microwave background. In the CLASS VPMs, parallel transport of the mirror is maintained by a voice-coil actuated flexure system which will translate the mirror in a repeatable manner while holding tight parallelism constraints with respect to the wire array. The wire array will use 51 μm diameter copper-plated tungsten wire with 160 μm pitch over a 60 cm clear aperture. We present the status of the construction and testing of the mirror transport mechanism and wire arrays for the CLASS VPMs.

245.15 – The Cosmology Large Angular Scale Surveyor

Tobias Marriage[1], Aamir Ali[1], Mandana Amiri[5], John W. Appel[1], Derek Araujo[6], Charles L. Bennett[1], Fletcher Boone[1], Manwei Chan[1], Hsiao-Mei Cho[3], David T. Chuss[2], Felipe Colazo[2], Erik Crowe[2], Kevin Denis[2], Rolando Dünner[4], Joseph Eimer[1], Thomas Essinger-Hileman[1], Dominik Gothe[1], Mark Halpern[5], Kathleen Harrington[1], Gene Hilton[3], Gary F. Hinshaw[5], Caroline Huang[1], Kent Irwin[9], Glenn Jones[6], John Karakla[1], Alan J. Kogut[2], David Larson[1], Michele Limon[6], Lindsay Lowry[1], Nicholas Mehrle[1], Amber D. Miller[6], Nathan Miller[2], Samuel H. Moseley[2], Giles Novak[7], Carl Reintsema[3], Karwan Rostem[2], Thomas Stevenson[2], Deborah Towner[2], Kongpop U-Yen[2], Emily Wagner[1], Duncan Watts[1], Edward Wollack[2], Zhilei Xu[1], Lingzhen Zeng[8]
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Some of the most compelling inflation models predict a background of primordial gravitational waves (PGW) detectable by their imprint of a curl-like "B-mode" pattern in the polarization of the Cosmic Microwave Background (CMB). The Cosmology Large Angular Scale Surveyor (CLASS) is a novel array of telescopes to measure the B-mode signature of the PGW. By targeting the largest angular scales (>2°) with a multifrequency array, novel polarization modulation and detectors optimized for both control of systematics and sensitivity, CLASS sets itself apart in the field of CMB polarization surveys and opens an exciting new discovery space for the PGW and inflation. This poster presents an overview of the CLASS project.

245.16 – Enabling Dark Energy and Beyond Science with Precise Absolute Photometry

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We have obtain WFC3/IR observations of 15 carefully selected stars with the immediate objective of establishing their Absolute Physical Flux (ABF), and an ultimate goal of achieving the sub-1% absolute photometric accuracies required by Dark Energy science with JWST and other facilities. Even with the best data available, the current determination of ABFs is plagued by the reliance on the Vega photometric system, which is known to be problematic primarily due to the fact that Vega is a pole-on rapid rotator with an infrared excess from its circumstellar disk! which makes it difficult to model. Vega is also far too bright for large aperture telescopes. In an effort to remedy these difficulties, teams from the National Institute of

Standards (NIST), the University of New Mexico, Johns Hopkins University and STScI have begun to develop a catalog of stars that have spectral energy distributions that are tied directly to NIST (diode) standards with very precisely determined physical characteristics. A key element in this pursuit has been the efforts at STScI to measure the spectra of many of these objects with STIS. We discuss our program to extend this effort into the near-IR which is crucial to reliably extend the SEDs to longer wavelengths, including the mid IR.

245.17 – Cross-Correlation Functions of Galaxies with Grouped and Isolated Quasars in SDSS DR10

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The correlation between galaxies and quasars has been well documented. Here we investigate if pairs and groups of quasars trace more surrounding galaxies than their isolated counterparts. Utilizing 67,961 quasars from the Sloan Digital Sky Survey (SDSS) Data Release 10, a nearest neighbor algorithm was constructed to find grouped and isolated quasars. The results were then compared to 1.7 million galaxies from SDSS DR10 to form quasar-galaxy two-point cross-correlation functions at different quasar redshifts. As expected, galaxies show a stronger correlation with pairs and groups of quasars than with isolated quasars at all redshifts. Our results could help predict regions in the sky where there may be distant galaxies with redshifts z>1.0.

245.18 – Primordial Inflation Explorer (PIXIE): Limits of Systematic Effects in CMB Measurement

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The Primordial Inflation Explorer (PIXIE) is an Explorer-class mission to characterize the spatial, polarization and frequency spectra of the Cosmic Microwave Background (CMB) radiation. PIXIE's multi-moded optics differ significantly from the focal plane arrays employed by the current generation of ground-based or balloon experiments. We calculate uncertainties due to potential systematic effects arising from the instrumental limitations such as beam asymmetry and resolution, polarization diplexer inefficiencies, calibration errors, and observational coverage variations. Mitigation strategies for foreground galactic dust, lensing, line emission, and the purity of the CMB polarization power spectrum are discussed in detail. End-to-end simulations incorporating the influence of realistic instrument imperfections are explored and the system performance is shown to be robust.

245.19 – The Discovery and Characterization of Surprisingly Luminous Galaxy Candidates at z~9-10: The Power of Combining HST and Spitzer

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Contributing teams: XDF/HUDF09 team

Deep observations with the WFC3/IR camera on HST have pushed the frontier for galaxies in the young universe to z~9-11, just ~450 Myr from the Big Bang at the heart of the reionization epoch. However, until recently only a small number of intrinsically very faint galaxies had been identified at these redshifts from extremely deep WFC3/IR data in the XDF/HUDF and the GOODS-South field and from the CLASH cluster survey. This changed with our recent analysis of the completed CANDELS survey data over the GOODS-North/HDF-N field. We discovered four surprisingly bright Lyman-break galaxy candidates at z~9-10, the brightest of which has a most probable redshift of z~10.2. These sources are a factor ~10-20x more luminous than any previous candidate at redshifts z~9-10. The high number of such luminous sources suggests that star-formation was highly stochastic in the very early universe resulting in large field-to-field variance. Furthermore, three of these bright candidates show significant detections in Spitzer/IRAC, substantially enhancing the probability that these galaxies are at z~9-10. The IRAC data probes the rest-frame optical light and indicates that these sources already had a stellar mass of 10^9 Msol at a cosmic time of only 450-500 Myr. While the overall star formation rate density of galaxies with SFR>0.7 Msol/yr has been shown to increase rapidly in just 200 Myr from z~10 to z~8, the discovery of these luminous sources has very promising implications for the detection of galaxies at times significantly earlier than 450 Myr with JWST.

245.20 – Simulation of interferometric observations of cosmic microwave background polarization

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We present results of simulated interferometric observations of cosmic microwave background polarization. Our simulation pipeline allows for arbitrary interferometer geometry, sky rotation, etc., and includes a variety of possible systematic errors. We perform image reconstruction and two forms of power spectrum estimation (maximum likelihood and Gibbs sampling). The results indicate the level to which various systematic errors (e.g., pointing errors, gain errors, beam shape errors, cross-polarization) must be controlled in order to achieve a successful detection of primordial B modes.

246 – Evolution of Galaxies Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

246.01 – The Average Properties Of CaII And NaI Absorbing Galaxies From Stacked Quasar Spectra

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Cherinka & Schulte-Ladbeck (2011, AJ 142, 122) used the Sloan Digital Sky Survey SDSS/DR7 to construct a sample of 97,489 galaxy/quasar projections at impact parameters up to 100 kpc from the foreground galaxy, then searched the quasar spectra for CaII and NaI absorption within 500 km s-1 from the galaxy's velocity. Here, we split the sample into absorbers, ?3?, and non-absorbers, <2?, for galaxy redshifts z>0.01, and perform a spectral stacking analysis to derive average properties. In the 19 CaII absorbers, the CaIIK line has EW = (1.46±0.03) Å and vFWHM = (725±17) km s-1, and the H line has EW = (0.84±0.03) Å and vFWHM = (746±28) km s-1. The doublet is partially saturated with a ratio of ~1.7. We find weak NaI with EW = (0.16±0.02) Å and vFWHM = (294±38) km s-1. We detect no CaII features in 12,545 CaII non-absorbers. We do detect NaI with EW = (0.10±0.04) Å and vFWHM = (930±32) km s-1. In 36 NaI absorbers, the blended NaI feature has EW = (1.86±0.03) Å and vFWHM = (813±11) km s-1. We detect no CaII. We detect a weak NaI feature in the stack of 11,520 NaI non-absorbers, EW = (0.035±0.028) Å and vFWHM = (917±67) km s-1. We detect no CaII. Our main results are: 1. NaI absorption is ubiquitous. 2. CaII and NaI in absorbers is detected to our cutoff of 100 kpc. 3. No significant differences between absorbers and non-absorbers for a wide range of galaxy properties (size, color, concentration index, surface brightness profile) 4. Absorbers and non-absorbers occupy similar impact-parameter—luminosity space. 5. No difference in galaxy inclination, or azimuthal angle distribution, between absorbers and non-absorbers 6. Covering fractions of CaII and NaI are higher than non-absorbers, ~5% within 10 kpc, and drop off significantly, to <1% above 10 kpc. 7. Covering fractions within 10 kpc are slightly higher for luminous galaxies >0.1 Lr*, 12.5% for CaII and 6% for NaI, than for low-luminosity galaxies. Acknowledgements: We acknowledge the use of SDSS, NASA ADS, NED, and HyperLeda.

246.02 – Probing Star Formation in Polar Ring Galaxy NGC 2685

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NGC 2685 is an exceptional early type (S0) galaxy due to its two unusual apparent ring structures: a coplanar ring of dust and gas that shows signs of recent star formation, as well as a UV bright polar ring, perpendicular to the center of the galaxy. Using GALEX images in the FUV and NUV, as well as IRAC 3.6μm and WISE 22μm observations, star formation rates (SFRs) are determined for regions within the galaxy, including sections of the polar ring and extended gas ring. Using HI moment maps obtained from Josza et al. (2009) gas surface densities are calculated in these regions. The galaxy is found to have a relatively low overall SFR with respect to the amount of HI observed. We investigate variations of SFR and gas density within the galaxy and observe the correlation between these quantities in this relatively inefficient star forming environment. We discuss NGC 2685 in the wider context of apparently rejuvenated early type galaxies, which are increasingly found to have low levels of SF taking place despite the presence of occasionally significant amounts of HI.

246.03 – SAMI Galaxy Survey: Spectrally Dissecting 3400 Galaxies By the Dozen

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Contributing teams: The SAMI Galaxy Survey team

More than 440 mapped, less than 3000 to go in the Sydney-AAO Multi-object IFU (SAMI) Galaxy Survey! SAMI uses novel, photonic fused-optical fiber "hexabundles" that were developed successfully at The University of Sydney and the Australian Astronomical Observatory AAO), with support from the Australian Research Council Centre of Excellence for All-Sky Astrophysics (CAASTRO). The SAMI Galaxy Survey, led by Assoc. Prof. Croom, is backed by an international team. This spectro-**bolometric** survey mitigates against "aperture effects" that may mislead when stacking single-fiber galaxy spectra. We seek to answer questions such as "what is the physical role of environment in galaxy evolution? How is stellar mass growth and angular momentum development related in galaxies? How does gas get into and out of galaxies, and how do such flows drive star formation?" SAMI maps stellar and gas properties with 13 integral-field units (IFU) plugged onto a dozen galaxies over the 1° field of the AAT prime-focus corrector. 78% of each bundle's area is filled by sixty-one 1.6-arcsec diameter fibers that are packed closely into concentric circles then their etched, thinned cladding is fused without deforming their cores. The fiber hexabundles route to the bench-mounted AAOmega double-beam spectrograph to cover simultaneously 373-570 nm at R=1730 and 620-735 nm at R=4500. Full spatial resolution of the observing site is recovered by dithered exposures totaling 3.5 hours per field. Target stellar masses generally exceed 10^8 M™, and span a range of environments:

?650 are within clusters of virial mass $10^{14\text{-}15}$ M™ at 0.03 < z < 0.06, the rest are in the z < 0.1 field with extensive frequency data ancillary to the GAMA Survey. We display some key early results of major science themes being addressed by the SAMI survey team, from rotation curve dependence on group halo mass, through galaxy winds and AGN feedback mechanisms, to oxygen abundance gradients, *kinematic* decomposition of galaxies into structural components to refine the T-F and FP scaling relations, and aperture effects. Our large sample size enables study of environmental dependencies. As the SAMI survey executes over the next 2.5 years, these will come into sharp focus.

246.04 – Stellar Masses, Star Formation Rates and X-ray Constraints on Galaxies in the Coma Cluster

Greg Hrinda[1], Tyler D. Desjardins[2], Ann E. Hornschemeier[3], Sarah Gallagher[2], Derek Hammer[4], Neal A. Miller[5], Andrew Ptak[3], Panayiotis Tzanavaris[6, 3], Kelsey E. Johnson[7], Lisa May Walker[7]
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We report on new measurements of star formation rates and stellar masses in the "infall" region of the nearby Coma cluster of galaxies. This region is approximately 1 Mpc from the cluster core, where relatively gas-rich galaxies are interacting with the hot intracluster medium, providing an important view of the impact of cluster processes on galaxy evolution. We have used infrared and ultraviolet data available from both ground and spaced-based observations to make these measurements. The star formation rates and stellar mass values were verified via comparison with published results in the Coma core as well as the Sloan Digital Sky Survey spectral measurements. The infall region has also been observed by XMM-Newton to faint limits to obtain X-ray luminosities for the galaxies in this field. Specifically, we present X-ray photometry of approximately 20 galaxies with XMM-Newton coverage to constrain the X-ray – SFR correlation in a cluster environment. This project was supported by the Baltimore Excellence in STEM Teaching program via summer internship funding to Hrinda.

246.05 – The X-ray Properties of PS1 Optical Galaxy Survey Galaxies

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Through the 2013 Baltimore Excellence in STEM Teaching (BEST) program for high school science teachers sponsored by NASA and Towson University of Maryland, we studied the association of x-ray luminosity with star formation rates and stellar masses estimated from optical images in the PS1 Optical Galaxy Survey (POGS) project. POGS is an ongoing citizen science program in which maps of star formation rate, stellar masses and other parameters are computed based on pixel-by-pixel spectral energy distribution fitting of Pan-STARRS and Sloan Digital Sky Survey photometric data (later to be expanded to include WISE and Galex images). The computation of these models is distributed using BOINC. The sample for this pilot study was based upon galaxies meeting the POGS selection criteria (most galaxies north of declination -30 degrees) with high Chandra exposure times, a redshift of less than 0.01, and that had been processed by POGS as of July 2013, resulting in 67 galaxies. We will discuss our preliminary results and prospects for expanding the project to the entire catalog of galaxies covered by both POGS and the X-ray archive and more detailed analysis of regions within galaxies with sufficient X-ray flux.

246.06 – What Makes a Tidal Tail?

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Galaxy interactions are famous for creating some of the most visually stunning scenes in astronomy, particularly in the cases of tidal tails. These chaotic regions are known to house breeding grounds for young stellar clusters, as shown through past imaging and spectroscopic studies, but the underlying material remains a mystery. While we know that gas is easily stripped from the parent galaxies, what about the stars? The presence of an older stellar population is crucial to dynamical simulations of tidal tails, but has not yet been confirmed by observation. We use the twin tidal tails of NGC3256 as a case study for determining the presence of an old, underlying stellar population. Newly acquired ugriz Gemini data allows us to distinguish between young and old stars, while previous HST data pinpoints the locations of these objects. Deep imaging surveys have often been used to detect tidal features, including these ancient relics, but our survey will be the first to measure the colors of such objects. This will lead us to place constraints on the original composition of the material that was ejected from the interacting/merging galaxies, and the star formation history.

246.07 – EDGES: A Mass Estimate of the Tidal Streamer in M 63

Shawn Staudaher[1], Daniel A. Dale[1], Liese van Zee[2], Kate L. Barnes[2]
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Contributing teams: EDGES

We present new results from the Extended Disk Galaxy Exploration Science (EDGES) Survey. EDGES is a *Spitzer Space Telescope*, volume-limited, ultra-deep, $\mu(3.6\mu m)=30$ mag $arsec^2$, wide-field (5 R_{25}) survey of 92 galaxies designed to detect and measure the faintest extended features associated with nearby galaxies. The extraordinary depth of EDGES allows measurements of the mass surface density of extended features to less than 0.1 $M^{\text{™}}$ pc^2. From the EDGES data-set we present mass estimates for the progenitor galaxy of the tidal streamer found in M 63.

246.08 – Early-Type Galaxy Star Formation Histories in Different Environments

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We use very high-S/N stacked spectra of ?29,000 nearby quiescent early-type galaxies (ETGs) from the Sloan Digital Sky Survey (SDSS) to investigate variations in their star formation histories (SFHs) with environment at fixed position along and perpendicular to the Fundamental Plane (FP). We separate galaxies in the three-dimensional FP space defined by galaxy effective radius Re, central stellar velocity dispersion ?, and surface brightness residual from the FP, ?Ie. We use the SDSS group catalogue of Yang et al. to further separate galaxies into three categories by their "identities" within their respective dark matter halos: central "Brightest Group Galaxies" (BGGs); Satellites; and Isolateds (those which are "most massive" in a dark matter halo with no Satellites). Within each category, we construct high-S/N mean stacked spectra to determine mean singleburst ages, [Fe/H], and [Mg/Fe] based on the stellar population synthesis models of R. Schiavon. This allows us to study variations in the stellar population properties (SPPs) with local group environment at fixed structure (i.e., fixed position in FP-space). We find that the SFHs of quiescent ETGs are almost entirely determined by their structural parameters ? and ?Ie. Any variation with local group environment at fixed structure is only slight: Satellites have the oldest stellar populations, 0.02 dex older than BGGs and 0.04 dex older than Isolateds; BGGs have the highest Fe-enrichments, 0.01 dex higher than Isolateds and 0.02 dex higher than Satellites; there are no differences in Mg-enhancement between BGGs, Isolateds, and Satellites. Our observation that, to zeroth-order, the SFHs of quiescent ETGs are fully captured by their structures places important qualitative constraints on the degree to which late-time evolutionary processes (those which occur after a galaxy's initial formation and main star-forming lifetime) can alter their SFHs/structures.

246.09 – Requirements for Radial Migration: How does the migrating fraction depend on stellar velocity dispersion?

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Radial migration is a way to rearrange the orbital angular momentum of stars in an spiral disk without inducing kinematic heating. When radial migration is very efficient, a large fraction of disk stars experience significant changes in their orbital angular momenta in a short period of time. Such scenarios have strong implications for the chemical and kinematic evolution of disk galaxies. We have undertaken an investigation of the physical dependencies of the efficiency of radial migration on stellar kinematics and spiral structure by deriving the fraction of stars that can migrate radially given certain conditions. In order for a star in a spiral disk to migrate radially, it must first be "captured" in a family of resonant orbits near the radius of corotation with a spiral pattern. Thus far, the only analytic criterion for capture has been for stars in circular orbits. We present the capture criterion for stars on non-circular orbits in a disk galaxy. We then use our analytically derived capture criteria to model the radial distribution of the captured fraction in an exponential disk with a flat rotation curve as well as the dependence of the total captured fraction in the disk on the radial component of the stellar velocity dispersion ($?_R$) and the amplitude of the spiral perturbation to the underlying potential at corotation ($|?_s|_{CR}$). We find that the captured fraction goes as $Exp[-?_R^2/|?_s|_{CR}]$.

246.10 – Determining the Importance of Shocks on Galaxy Evolution in Compact Groups: a Herschel and CARMA View

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Understanding the evolution of galaxies from starforming blue cloud objects into quiescent red sequence galaxies has been revolutionized by observations taken with the Herschel Space Observatory, allowing astronomers to probe both the cold dust as well as the cool ISM in a large set of galaxies, with unprecedented sensitivity. Recent Herschel observations of [C II], a known tracer of star formation, in Hickson Compact Groups of galaxies (HCGs) has shown that [C II] can also be highly excited in shocks. CARMA CO observations of these [C II]-bright HCGs therefore shed light on the impact of shocks on the excitation of the ISM, as well as the starforming (molecular) material. I will present preliminary results from our Herschel-CARMA combined observations of HCGs, which are able to tell us about the synergistic relationships between shocks, star formation and the cool ISM in the context of galaxy evolution.

246.11 – Infrared and X-ray Cooling in the Taffy Bridge: Herschel and Chandra weigh in!

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We present new Herschel far-IR spectral-line maps ([CII] and [OI]), Herschel photometry and Chandra X-ray imaging of the "Taffy Galaxies" (UGC12904/5) and the radio-emitting "bridge" which lies between them. There is evidence that the galaxies have suffered a head-on collision (delta-V = 600 km/s) in the past in which the two galaxies passed through each other almost face-on, and have created a highly turbulent "splash bridge" between them. Previous observations made with Spitzer have shown that the bridge contains a large mass of warm molecular hydrogen which is too warm and luminous to have been heated by young stars which seem to be mainly absent from the bridge. Our new observations show that 1) the soft X-ray emission is too faint to account for the warm H2, 2) [CII] emission, like warm H2, is enhanced in the bridge, while [OI] is weak. Herschel far-IR photometry also show the existence of cool dust in the bridge and a strong truncation of the normal dust emission in the outer disk of the southern galaxy probably caused by viscous stripping in the collision. The results suggest that, like a similar region in Stephan's Quintet, gas which is turbulent and shock heated can emit strongly in [CII] without the need to invoke strong UV emission from star formation. The C+, cool dust and X-rays seem to define the region in the bridge which is currently undergoing the most turbulent heating. Surprisingly, we note a significant offset between the coldest and most massive molecular hydrogen clouds (see in CO 1-0) and the Herschel-detected cool dust, suggesting a major difference in gas to dust ratio from the less turbulent cold molecular gas to the warmer "shock" excited regions. This may suggest an age gradient in shock processing transverse to the direction of movement of the two galaxies. The reason for this is not yet fully understood, but may relate to the counter-rotation of the galaxies before they collided. The results, like that of Stephan's Quintet, imply that the C+, one of the main coolants of the diffuse ISM, can be boosted by turbulence and shocks. These regions may suppress star formation until the kinetic energy has had time to dissipate.

246.12 – Arecibo Galaxy Environment Survey: Visualizing the Volumes of Isolated Galaxies NGC 5523 & UGC 2082

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The Arecibo Galaxy Environment Survey (AGES) is a neutral hydrogen galaxy survey. It is searching for galaxies by 21cm emission from neutral hydrogen gas in their interstellar media. I analyzed the isolated NGC 5523 & UGC 2082 regions, two 5 square degrees fields obtained with the Wideband Arecibo Pulsar Processor (WAPP) correlators covering a redshift range of z ~ 0 - 0.06. A number of possibly interacting galactic systems were identified by their HI structure. Particularly, a lack of companions to NGC 5523 was found to a lower limit of 9*10^6 solar masses (NGC 5523 is at a distance of approximately 20 Mpc). Additionally, I studied the reliability and completeness of automated source extraction techniques. Finally, I employed novel forms of data visualisation in order to investigate the volume behind these two isolated galaxies, which resulted in the production a catalogue containing measured parameters such as flux, HI mass, velocity width, position fitting, mass-to-light ratios and gas deficiencies for the detected sources.

246.13 – Mapping the Characteristics of NCG 7081 as a Function of Galactic Radius

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We have studied six individual star forming regions in galaxy NGC 7081 in order to determine the radial dependence of galactic properties such as star formation rate, extinction, and nebular abundance. Using the SNIFS Integral Field Unit on the 2.2 meter telescope on Mauna Kea, we acquired spectroscopic data consisting of 225 spatial spectra covering an area of 6x6 arcmin2 for each region and after reduction, produced a combined spectrum for each region. We correct for the Milky Way extinction E(B-V) = 0.0576±0.0006, the under lying stellar absorption by fitting the continuum with Starlight, a spectral energy distribution package, and considered different (Cardelli, Clayton & Mathis, Gordon et al, and Calzetti) to correct for the galaxy's internal extinction. We present the star formation rate, extinction, and nebular abundance of the individual HII regions. Through studying these 6 regions and their galactic properties as a function of galactocentric radius, we will be able to piece together the history of the galaxy as a whole. This work was partially supported by the National Science Foundation Grant AST 0909240 and National Science Foundation's REU program (NSF Award AST-0851892).

246.14 – The Sagittarius Dwarf Galaxy Tidal Debris in the south Galactic Cap

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We characterize the spatial properties of the Sagittarius dwarf galaxy tidal debris, both primary and secondary (bifurcated) tidal tails, in the south Galactic cap. The Sagittarius dwarf galaxy is currently being ripped apart by tidal forces from the Milky Way galaxy. The spatial density of turnoff stars from the Sloan Digital Sky Survey Data Release 8 are fit using statistical photometric parallax with half a petaFLOPS of computing power from the MilkyWay@home volunteer computing platform. The secondary tail appears to be significantly wider than the originally detected primary tail. These results are compared with the leading tidal tail stream density measured in the north Galactic cap. This research was funded by NSF grant AST 10-09670.

246.15 – Exploring Evolution Through the Effects of Galaxy-Galaxy and Group Interactions on Gas Content

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Galaxy-galaxy interactions are a driving force in galaxy evolution, producing changes in color, morphology, metallicity and enhancing star formation. Many factors contributing to these changes have been well studied such as environment and orientation of the interaction, however studies of the gas content have been limited. To address the question of how interactions affect the gas content of galaxy pairs, we present results from two studies taking different approaches to the question. We present results from a combined optical and HI 21 cm study of 102 galaxy pairs with projected separations up to 120 kpc and velocity differences less than 500 km/s. These pairs were selected from the SDSS spectroscopic survey and were also observed by the ALFALFA HI 21 cm survey. We use these data to study how interactions effect the SFE and HI gas content of these systems. From the second study we present initial results from VLA D-array observations of a galaxy group in which interactions appear to be removing much of the cold gas from the galaxies creating a large reservoir in the inter-group medium. We investigate how this removal of gas and subsequent reservoir impact the evolution of the galaxies within the group, particularly two systems which are transitioning through the green valley. This work has been supported by NSF grant AST-000167932 and a George Mason University Presidential Fellowship.

246.16 – A Study of Galaxy Populations with Red [3.4]-[4.6] Colors

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The Wide-Field Infrared Sky Survey (WISE) provides a look at the dust emission in galaxies over the entire sky. We match this catalog with SDSS DR7 in order to calculate the luminosity and stellar mass functions for galaxies with z<0.1 as a function of [3.4]-[4.6] micron color. The number density of galaxies with red infrared colors ([3.4]-[4.6] > 0.5) rises toward the low mass and low luminosity end. This increase in the dust emission in lower mass galaxies, which are generally thought to be younger and more pristine, is important to understanding the mechanisms that are driving this emission. Other studies have associated red [3.4]-[4.6] colors with star formation, AGN activity, and shocks. We include the HI 21 cm properties of these galaxies in order to study the impact of the gaseous environment and gas-to-stars ratio on these systems and the mechanisms that might be driving the heating of the dust. This study was funded by NSF grant AST-000167932.

246.17 – Galaxy Zoo 2: Statistics of Morphological Sub-Populations

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In the past, large galaxy surveys have been mapped in color-magnitude space, and fit to Schechter luminosity functions, enabling detailed, quantitative descriptions of their distributions. A similar approach is implemented, for many of the morphological classification groups available in the Galaxy Zoo 2 data release. We investigate photometry of elliptical galaxies, spiral galaxies, barred galaxies, and their sub-populations. Several of those populations are found to have qualitatively different distributions from the full sample, and we experiment with methods of fitting and distinguishing between them. Such methods include peak comparison, ridgeline function fitting, and statistical bootstrapping.

246.18 – Insight into Gas Processing in Compact Groups of Galaxies

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Compact groups of galaxies provide a unique environment to study the evolution of galaxies amid continuous gravitational encounters. These groups provide a nearby environment with conditions similar to those in the earlier universe when galaxies were assembled and give us the opportunity to witness hierarchical formation in progress. In order to understand how the compact group environment affects galaxy evolution, it is important to study the gas and dust processes in these groups. Single-dish neutral hydrogen (HI) observations of compact groups allow us to measure the HI mass of each group in our survey, as well as to determine whether there is a significant amount of HI in the intragroup medium. We compare the HI to stellar mass ratio with mid-IR indicators of star formation and optical [g-r] color to search for correlations between gas content and star formation activity. We find that quiescent galaxies tend to live in HI-poor groups, and galaxies with active star formation are more commonly found in HI-rich groups regardless of the location and distribution of the HI gas, though we do see "rogue" galaxies whose activity does not correlate with group HI content. Ultimately, we will use these results to understand gas processing and the ISM in environments similar to that in the earlier Universe.

246.19 – Metallicities of Extraplanar H II Regions in Edge-on Spiral Galaxies

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We present spectroscopy of thick disk H II regions in the edge-on spiral galaxies NGC 891 and NGC 4013 using MODS on the LBT and LRIS on KECK. These star forming regions, located at large z-heights from the galactic plane, provide a direct probe of the origins of thick disk interstellar material. In NGC 891, the derived H II region metallicity is consistent with the metallicity found in the plane but is located at a distance of z ~ 650 pc beyond the plane. This region was likely formed from material that was expelled from the plane in energetic processes consistent with a galactic fountain model. Whereas, in NGC 4013, the H II region, located at z ~ 850 pc beyond the plane, has a much lower derived metallicity compared to the galactic plane. This lower metallicity H II region implies that the original interstellar material that formed these stars contained a mixture of both solar metallicity material and some fraction of lower metallicity material, characteristic of a galactic fountain in combination with infalling lower-metal material described by galactic accretion.

246.20 – Magellanic Clues to Spatially-resolved Extinction Corrections for Distant Galaxies in the HST/JWST Era

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Extinction by dust hampers our understanding of galaxies at all redshifts, and is not constant within or across the face of a

galaxy, nor from galaxy to galaxy. We presented an empirical method to correct galaxy images for extinction due to interstellar dust on a pixel by pixel basis, using only rest-frame 3.6 and 0.55 micron images. While this "β_V" method is approximate in nature, in its first application to a nearby spiral galaxy we produced extinction maps and revealed hidden coherent galaxy structures like a stellar bar and ridges of dust, while anomalous inferred central extinctions in several earlier-type disk galaxies proved powerful tracers of hidden AGN. This method is particularly promising for deep mid-IR imaging surveys with the James Webb Space Telescope in fields covered by HST in visible light, since their resolutions will be well-matched. Here we report on our follow-up investigation to explore the applicability, robustness, and fidelity of the β_V method on linear size scales from pc to kpc and in regions of varying star formation histories, metallicities, and dust content/distribution. We do so by combining WISE 3.4(Spitzer/IRAC 3.6) micron images of the LMC and SMC ---the nearest astrophysical laboratories with a range of sub-solar metallicities--- with 2MASS near-IR and OGLE-III multi-year V and I reference images and catalogs. We assess at ~1" (~0.25--0.35pc) resolution the properties of the stellar populations that contribute to the flux in each WISE(IRAC) resolution element using the 2MASS and OGLE-III data. That allows us to measure the observed and derive through modelling the inherent V-to-3.4(3.6) micron flux ratio per WISE(IRAC) resolution element. Subsequent resampling and PSF-matching at geometrically increasing scales from pc to kpc resolution elements allows us to assess the accuracy and fidelity of the method as a multi-variate function of the resolution, underlying stellar population mixture, physical environments, and projected distribution of dust. Resulting predicted β_{V,0} will serve as calibrations for the spatially-resolved extinction correction of galaxies at all redshifts where the method is proved reliable. This work is funded by NASA/ADAP grant NNX12AE47G.

246.21 – The Green Valley is a Red Herring: Different Evolutionary Pathways for Spheroidal and Disk Galaxies

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Contributing teams: Galaxy Zoo Citizen Scientists

Using SDSS+GALEX+Galaxy Zoo data, we show that the green valley in the color-mass diagram (between the blue cloud of star-forming galaxies and the red sequence of quiescent galaxies) is not a single transitional state through which most blue galaxies evolve into red galaxies. Rather, an analysis that takes morphology and UV colors into account makes clear that only a small population of blue galaxies moves rapidly across the green valley, after star formation is abruptly quenched and the morphology is transformed from disk to spheroid. In contrast, the majority of blue star-forming galaxies retain significant disks as their star formation rates decline very slowly. We detail a range of observations that lead to these conclusions, including UV-optical colors and halo masses, which both show a striking dependence on morphological type. We interpret these results in terms of how much gas is available for star formation. We conclude that disky galaxies are consistent with a scenario where the cosmic supply of gas is shut off, perhaps at a critical halo mass, followed by a slow exhaustion of the remaining gas over several Gigayears, driven by secular and/or environmental processes. In contrast, spheroidal galaxies require the gas supply and gas reservoir to be destroyed virtually instantaneously, with rapid quenching accompanied by a morphological transformation from disk to spheroid. This gas reservoir destruction could be the consequence of a major merger, and mergers could play a role in inducing black hole accretion and possibly AGN feedback in this minority of galaxies.

246.22 – A GBT HI Survey of the HALOGAS Galaxies

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We present preliminary results of deep neutral hydrogen (HI) observations with the Green Bank Telescope (GBT) of a select sample of galaxies in the WSRT Hydrogen Accretion in Local Galaxies (HALOGAS) Survey. The aim of these observations is to conduct a census survey of HI around a sample of galaxies, covering a wide range of masses and environments, to determine the origins of any discovered tidal interactions and accretion flows from the intergalactic medium. Our GBT maps of the HALOGAS galaxies are 4 square degrees with a sensitivity of ~ 20 mK and an angular resolution of 9'. Our 5? detection limit of ~ 10^{18} cm^{-2} for column density and channel size of 5.2 km s^{-1} allows for a deeper investigation into how galaxies accrete their gas from the surrounding environment, and how this gas is converted into stars. Our sensitivity to low column density values with the GBT is also well suited for searching the extended HI environment around the HALOGAS galaxies and their companions for evidence of tidal interactions between them. The HALOGAS survey provides an excellent observing sample that spans an extensive collection of galactic environments including different inclinations, Hubble types, systematic and

rotational velocities, and masses. We introduce initial comparisons of our GBT maps to the HALOGAS results, describe our observing technique and data reduction process, and discuss future work.

246.23 – The Local Cluster Survey: Probing Gas Stripping in Nearby Galaxy Groups and Clusters

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Contributing teams: Local Cluster Survey Team

The primary goal of the Local Cluster Survey is to measure the variations in the spatial extent of cold disk gas relative to the stellar disk for approximately 125 low-redshift group and cluster spiral galaxies (z < 0.037) in order to quantify the relative importance of the physical mechanisms that cause galaxies to evolve from blue, actively star-forming galaxies to red, passive galaxies. More specifically, environmentally-driven gas-depletion mechanisms are expected to preferentially remove gas from the outer radii of galaxies, so we are looking for signs that the gas is truncated relative to the stellar disk. The sample consists of 9 groups and clusters that span a range of X-ray luminosities, and all have optical photometry and spectroscopy from the SDSS, infrared 24-micron imaging from the Spitzer Space Telescope, and radio data from the ALFALFA survey. The wide areal coverage of these data allows us to track the evolution of disk gas from the dense cluster core to the surrounding field. Using GALFIT, we measure the effective radii in the r-band and at 24-microns. We find that the relative size of the gas disk with respect to the stellar disk decreases systematically as local density increases and as distance from the cluster center decreases. We also present a preliminary measure of the infrared luminosity function and quantify the evolution of the luminosity function with respect to intermediate redshift clusters. This material is based upon work supported by the National Science Foundation under Grant AST-0847430 and AST-1211005.

246.24 – Physical and Morphological Parameters of [O II] Emitting Galaxies in the HETDEX Pilot Survey

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The Hobby-Eberly Dark Energy Experiment (HETDEX) pilot survey found 284 [O II] λ3727 emitting galaxies in a 169 arcmin^2 field of sky in the redshift range 0 < z < 0.57. This sample provides a bridge between studies in the local universe and higher-redshift [O II] surveys. We present an analysis of the star formation rates (SFRs) of these galaxies as a function of stellar mass as determined via spectral energy distribution fitting. The [O II] emitters fall on the "main sequence" of star-forming galaxies with SFR decreasing at lower masses and redshifts. The mass specific SFR increases for lower mass objects, supporting the idea that more massive galaxies formed more quickly and efficiently than their lower mass counterparts. Examination of the morphologies of the [O II] emitters reveals that their star formation is not a result of mergers. The equivalent widths of the [O II] emission lines trend larger with larger mass galaxies. The half-light radii of the galaxies indicate that they have non-evolving physical sizes.

246.25 – 850 μm source counts from a high-resolution survey with ALMA

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The source counts of submillimeter-selected galaxies provide important clues to the evolution of massive, dust-obscured galaxies forming in the early Universe. While existing surveys using single-dish telescopes over the past 15 years have detected thousands of dusty starburst galaxies at z > 1, using their observed number density to constrain models of galaxy evolution is challenging due to the low spatial resolution (10-30") of these observations: distinguishing between a single, ultra-luminous submillimeter source versus a pair of less luminous, merging galaxies blended by the large beam is not possible. We present a measurement of the 850 μm source counts determined directly from high-resolution data taken with ALMA, covering a total area of 7 sq. arcmin down to 0.2-0.4 mJy rms. With a spatial resolution of ~0.5" (~4 kpc at z =2), source blending is not expected to be an issue with these data, except for close pairs in the final stage of merging. The methods to derive the source counts from interferometric measurements presented here demonstrate the need for careful accounting of survey biases from these data, which will be important for use in future dedicated galaxy surveys with ALMA.

246.26 – Dependence of Galaxy Clustering on Stellar Mass and sSFR at z~1

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The clustering of galaxies is a good tool to investigate how galaxies are connected to their host dark matter halos. We select galaxies based on wide and deep photometric data covering 8 sq. deg. from UKIDSS DXS and CFHTLS. The angular correlation function is measured for various sub-samples split by stellar masses and specific SFRs (sSFRs). In addition, we use the halo occupation model to link galaxies with their host dark matter halos for stellar mass limited samples. Here we present the dependence of clustering on stellar masses and sSFRs and the stellar mass to halo mass relation at z~1. This result provides some hints about the evolution of galaxies.

246.27 – The Influence of Bars in Triggering Star Formation Since z = 1

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We present an analysis of star formation rates in a redshift-dependent fraction of galactic bars over 0.2 < z < 0.84 in 295 IR-bright luminous face-on spiral galaxies from the COSMOS 2 deg2 field. Every galaxy in our sample has high-quality multi-frequency data. We find that the star formation rate does not dramatically depend on the presence of a galactic bar at different redshifts. When we observe the full sample of galaxies that is not biased towards IR-bright galaxies we see the same trend. While the presence of a bar dramatically changes the kinematics of a galaxy and can cause increased star formation in the central kilo parsec, it does not have a measurable effect on boosting the overall star formation rate in the galaxy when compared to unbarred galaxies. When star formation in IR bright galaxies is compared to mass at a specific redshift bin then a trend of increasing star formation with decreasing mass is present at low redshifts.

246.28 – Luminosity and Color Dependence in Galaxy Cross-Correlations since z = 1 in PRIMUS

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I present small-scale galaxy cross-correlation measurements from the PRIsm MUlti-object Survey (PRIMUS) as a function of color, luminosity, and redshift. We measure the real-space clustering of ~50,000 galaxies from PRIMUS, over a redshift range 0.2 < z < 1, by cross-correlating spectroscopic PRIMUS galaxies with a tracer population of galaxies selected from imaging catalogs. In agreement with previous work, we find strong clustering differences between blue and red galaxy populations. Our results indicate luminosity-dependent clustering, but this luminosity dependence further varies depending on color and physical scale. We interpret our results using a halo abundance model.

246.29 – Using Morphology to Identify Galaxy Mergers at High Redshift

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Contributing teams: CANDELS Collaboration

We analyzed a set of 22,003 galaxies in three of the five CANDELS fields: COSMOS, UDS, and GOODS-S, in order to determine how well automated image statistics did with classifying galaxy morphology and mergers at high redshifts (z > 1). For each galaxy in our set, we have multi-wavelength data, photometric redshifts from SED fitting, visual classifications from the CANDELS structure and morphology group, and automated image statistics. The redshifts of our sample range from z = .01 to 4 with <z> = 1.33. We constructed a conservative set of 1,914 galaxies that we believe to be mergers and interactions. Of this set of merging galaxies, 1,343 were at a redshift greater than z = 1. We also identified a conservative set of 535 spheroids and a set of 2,902 disks. Several different quantitative methods were then used to attempt an automated classification of these visually classified samples. Of the different image statistics, we found M20 and Gini to be the most successful at picking out high redshift mergers and morphological characteristics. Blancato was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program (AST-1262829).

246.30 – 2D kinematics and physical properties of distant galaxies

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The study of the physical properties of high-redshift galaxies has become one of the major goals of extragalactic astronomy. In particular the mass-assembly history of galaxies have been the focus of many studies at redshift 1 to 3. We present recently published results obtained from Integral Field NIR Spectroscopy of a sample of 13 high-z (1 < z < 4) star-forming galaxies (4<230 M_sun/yr). We spatially resolved the kinematics using bright rest-frame optical emission lines, allowing studies of dynamical masses, SFRs, Tully-Fisher relations and metallicities at these "key" epochs. Using this data, we can set constrains on the formation and evolution of this galaxies, during an epoch of when we expect strong evolution in their masses and mass-to-light ratios. We found in particular relatively young stellar populations (<1.5 Gyr) in our objects and most of them have not yet converted the majority of their gas into stars (gas fraction > 50 per cent). Finally we show that those of them which already have a stable disc will probably have their final stellar mass similar to the present-day spirals, to which these rotating systems can be seen as precursors. We briefly present also an interesting result obtained for a comparable star-forming "clumpy" galaxy (A370-A5, z=1.341) discovered as an arc behind the lens cluster Abell 370 (z=0.374). The natural magnification due to massive galaxy clusters allows to spatially resolve and constrain the dynamics of young star forming galaxies 1 to 3 magnitudes fainter than those selected in blank fields. Thus, the study of lensed galaxies allows to probe a low mass regime of galaxies not accessible in standard observation. In this particular case, we found that the gas distribution and kinematics are consistent with a bipolar outflow with a range of velocities of v~100 km/s. References: Lemoine-Busserolle M. & Lamareille, F., 2010, MNRAS, 402, 2291 Lemoine-Busserolle, M. et al., 2010, MNRAS 401, 1657L

246.31 – Spectral Energy Distribution Fitting of HETDEX Pilot Survey Lyman-alpha Emitters in COSMOS and GOODS-N

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Contributing teams: HETDEX Team

We use photometry spanning from the rest-frame UV to the rest-frame NIR to fit the individual spectral energy distributions (SEDs) of 67 bright Ly-alpha emitting galaxies (LAEs) discovered in the HETDEX Pilot Survey. We find that bright LAEs in the redshift range 1.9 < z < 3.5 are quite heterogeneous. Our LAE masses span more than three orders of magnitude and are distributed in a manner that suggests that the objects are drawn in an almost uniform manner from the underlying galaxy mass function. This diversity is also reflect in the LAEs' dust content: while most of our objects are dust poor, some of the more massive LAEs are dust-rich, with differential extinctions as large as E(B-V) ~ 1.2. We find no significant correlation between half-light radius and stellar mass but we show that the Ly-alpha escape fraction does depend on mass, with low-mass systems being more efficient Ly-alpha emitters. Finally, we present evidence which suggests that there is an upper limit to the mass-specific star formation rates of Ly-alpha emitting galaxies.

246.32 – Galaxy Stellar Mass Functions from ZFOURGE/CANDELS: An Excess of Low-Mass Galaxies Since z=2 and the Rapid Buildup of Quiescent Galaxies

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Contributing teams: ZFOURGE, CANDELS

Using observations from the FourStar Galaxy Evolution Survey (ZFORUGE), we obtain the deepest measurements to date of the galaxy stellar mass function at 0.5<z<2.5. ZFORUGE provides well-constrained photometric redshifts made possible through deep medium-bandwidth imaging at 1-2μm. We combine this with *HST* imaging from the Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS), allowing for the efficient selection of both blue and red galaxies down to stellar masses ~$10^{9.5}$M_™ at z~2.5. The total surveyed area is 316 arcmin^2 distributed over three independent fields. Several studies at z≤1 have revealed a steepening of the slope at the low-mass end of the stellar mass function (SMF), causing an

upturn at masses $<10^{10}M_{\top}$ that is not well-described by a standard single-Schechter function. We find evidence that this feature extends to at least z~2, and that it can be found in both the star-forming and quiescent populations individually. The characteristic mass (M*) and low-mass slope (α) of a double-Schechter function fit to the SMF stay roughly constant at Log(M/M$_{\top}$)~10.65 and ~-1.5 respectively. The SMF of star-forming galaxies has evolved primarily in normalization, while the change in shape is relatively minor. This is not the case for quiescent galaxies: the depth of our imaging allows us to show for the first time significantly more evolution at Log(M/M$_{\top}$)<10.5 than at higher masses. We find that the total mass density (down to $10^{9}M_{\top}$) in star-forming galaxies has increased by a factor of ~2.2 since z?2.5, whereas in quiescent galaxies it has increased by a factor of ~12.

246.33 – SED Modeling of z~0.3-4 IR-Luminous Galaxies Using Hydrodynamic Simulations

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We use three-dimensional hydrodynamical galaxy merger simulations to further investigate the nature of a sample of ~340 24μm-selected (ultra) luminous infrared galaxies, (U)LIRGs, at z~0.3-4. All our sources have Spitzer IRS spectra -- the largest such sample outside the local universe. These spectra allow us to determine that the sample consists of a mixture of of starbursts, AGN and composites. We compare the IRS spectra and broadband photometry including Herschel far-IR data with theoretical SEDs based on GADGET-2 hydrodynamic merger simulations additionally processed through the SUNRISE radiative transfer code. Our goal is to test how the underlying physical conditions of galaxies, including the relative role of AGN, but also factors such as viewing perspective, affect the observed SED. This allows us to both test the observationally-determined AGN contributions to infrared luminosity, but also the level of systematic uncertainties therein. Lastly, our SED fitting provides insight into the merger stage of these sources (including isolated galaxies). We compare these results with HST imaging available for the bulk of the sample.

246.34 – A large JVLA molecular & continuum deep field: First continuum results

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We have used the JVLA to carry out the first molecular deep field observations covering a substantial cosmic volume. These 36 GHz (Ka-band) observations targeting CO(1-0) at z~2 and CO(2-1) at z~5.5 include a `wide' ~33 square arcmin mosaic in GOODS-N and a `deep' 6.5 square arcmin mosaic in COSMOS. Importantly, the 8 GHz bandwidth of the JVLA allows us to reach an unprecedented continuum rms of ~4.5 μJy/beam in GOODS-N and ~1.3 μJy/beam in COSMOS, opening up the possibility of detecting free-free emission – arguably the most direct tracer of dust-unbiased star formation – in z~2 star forming galaxies. We present first results based on individual continuum detections and stacking of optically selected galaxies using the unique multiwavelength coverage of COSMOS and GOODS-N. This study will allow us to directly trace the star formation in 'normal' galaxies during the epoch of galaxy assembly, ultimately pushing toward the faint end of the galaxy luminosity function at z~2.

246.35 – Tadpole Galaxies in the Near-Infrared

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Multiwavelength data are essential to provide a complete picture of galaxies' morphological properties at intermediate redshifts. Here we present results of a multiwavelength investigation of tadpole galaxies in the Hubble Ultra Deep Field. The galaxies in this study were drawn from a parent sample of tadpole galaxies from Straughn et al. (2006), which were selected from deep Hubble Space Telescope Advanced Camera for Surveys i'-band (F775W) data based on their distinct asymmetric knot-plus-tail morphologies. Visual classification of these galaxies in the deep Wide Field Camera 3 (WFC3) near-infrared

H-band (F140W) data reveal that the majority of these galaxies do not retain their distinct tadpole morphology in the near-IR and are generally classified as asymmetric disks; however, we show that this effect is largely due to resolution effects. The exception is the subset of higher redshift galaxies in our sample (z>2) which do generally keep their irregular morphology classification, in agreement with previous studies. The tadpole candidates span a redshift range of 0.5<z<3.6, and are on average ~half the age of the field sample and have higher stellar masses.

246.36 – Advantages to Having Low Pollution Environments: X-ray Binary Populations in Nearby and Distant UV-selected Galaxies

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We find evidence that the high-mass X-ray binary (HMXB) populations in relatively metal- and dust- poor UV-selected galaxies differs from those in other normal, local, star-forming galaxies, yielding higher 2-10 keV X-ray luminosities per star formation rate (SFR). Our metal and dust poor UV-selected galaxies are drawn from populations that span the majority of cosmic history -- ranging from Lyman break galaxies (LBGs) in the early Universe (z=1.5-4) to Lyman break analogs (LBAs) in the present-day Universe (z~0.1). Using X-ray stacking analyses of the 4 Ms Chandra Deep Field South (CDF-S) data with a sample of ~4000 z=1.5-4 LBGs, we find that the 2-10 keV X-ray luminosity per SFR (L_X/SFR) evolves mildly with redshift, consistent with predictions from X-ray binary population synthesis models. Additional Chandra observations of 6 relatively nearby (z~0.1) LBAs yield individual X-ray detections with elevated L_X/SFR ratios compared to local galaxies, but similar to the z>2 LBGs. In three LBAs, we can resolve the X-ray emission into individual point sources. For these LBAs, we find an excess number of ultra-luminous X-ray sources (ULXs) with L_X>10^40 erg/s compared to the average SFR-normalized X-ray luminosity function of normal star-forming galaxies. Based on these results, we interpret that the metal- and dust- poor LBAs and distant LBGs may yield higher total HMXB luminosities and more numerous ULXs than found in more representative local star-forming galaxies.

246.37 – The Fundamental Metallicity Relation of High-Redshift Emission-Line Galaxies

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We use data from the 3D-HST infrared grism survey to explore the Fundamental Metallicity Relation (FMR) of emission-line and Ly-α selected galaxies in the redshift range 2 < z < 2.3. We use the emission lines of oxygen ([O II] 3727, [O III] 5007), neon ([Ne III] 3869), and hydrogen (Hβ, H?) to estimate the galactic gas-phase metallicities of ~300 galaxies by combining the empirical line ratio indicators of R23, O32, and Ne3O2 (Maiolino et al 2008) in a statistically rigorous manner. We then use each object's broadband spectral energy distribution (SED) to derive its stellar mass, time-averaged star formation rate, and stellar extinction, and use its absolute Hβ flux to infer its instantaneous star formation rate. Our sample of galaxies, which span ~ 3 dex in stellar mass, allow us to define the epoch's FMR under the assumption that the SED-based stellar extinctions are applicable to the nebular emission. We show that the population of star-forming high-redshift galaxies has low metallicities, and falls well below the FMR of the local universe. This work was supported by NSF grant AST 09-26641.

246.38 – Understanding the Physical Conditions that Drive Line Emission in Nebular Regions of High-Redshift Galaxies

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We use the 3D-HST near-IR grism survey to study the physical conditions of the nebular regions within a statistically complete sample of ~ 300 emission-line selected star forming galaxies in the redshift range of 2.0 < z < 2.3. These spectra include the emission lines of oxygen ([O II] 3727, [O III] 5007), neon ([Ne III] 3869), and hydrogen (H-beta, H-gamma); when coupled with constraints on reddening and stellar mass derived from the objects' spectral energy distributions, these data allow us to explore parameters such as the systems' alpha-element abundances and ionization parameters. We try to reproduce these line ratios using theoretical models, such as CLOUDY, and compare line ratios with that of possible local analogs like Green Pea galaxies and Blue Compact Dwarfs. With our sample we can study any possible evolution in the physical conditions of star formation regions.

246.39 – Cosmic Variance in the Physical Properties of Ly-alpha Emitting Galaxies at 2<z<3

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Contributing teams: MUSYC Collaboration

We have used the Mosaic camera of the CTIO 4-m telescope to conduct a deep, narrow- band survey of Ly-alpha Emitting Galaxies (LAEs) over the redshift ranges 3.10 < z < 3.13 and 2.04 < z < 2.08 in two 0.3 square degree fields, one centered on the Extended Hubble Deep Field South and the other on SDSS 1030+05. These data, combined with our previous surveys of the Extended Chandra Deep Field South, give us a total survey volume of 400,000 Mpc^3 in z~2.06 and 500,000 Mpc^3 at z~3.1 which has been surveyed down to monochromatic line luminosities of log(L) ~42.3 ergs/s. We analyze the samples of Ly-alpha emitters found in the surveys, and present their luminosity, equivalent width, and color distributions as well as internal extinction and star formation rate. We also use these samples to search for diffuse Ly-alpha halos around LAEs at these redshifts. Most importantly, we use the information provided by our three survey fields to investigate the effect that cosmic variance has on these properties and on measurements of their evolution.

246.40 – Constraints on Lyα Blob Number Densities at z~2.1 and z~3.1

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Contributing teams: MUSYC Collaboration

Ly-alpha blobs are thought to be associated with regions over dense in compact Lyα emitters (LAEs) at the intersection of dark matter filaments, and may be the progenitors of today's galaxy clusters. Thus, a blob census can help explain the structure and formation history of these rare objects. We report the results of a deep narrow-band survey for Lyα blobs in three ~0.3 deg^2 fields: the Extended Chandra Deep Field South (at z = 2.06 and z = 3.1), the Extended Hubble Deep Field South (at z = 2.06 and z = 3.12) and the MUSYC field SDSS 1030+05 (at z = 2.06). Our surveys cover a total volume of 0.923 x 10^6 Mpc^3 at z = 2.06, and 0.871 x 10^6 Mpc^3 at z = 3.1; they are sensitive to blobs which have rest-frame equivalent widths greater than 30 Angstrom, and resolved blobs whose isophotal areas, defined using a surface brightnesses limit equivalent to a value of 5.5 x 10^{-18}~ergs/cm^2/s/arcsec^2 at z = 2.3, exceed a specified limit. We search for blobs expected in SDSS 1030+05 based on an observed over density of compact LAEs in the field (Gronwall et al, in prep.), and we use our results to place limits on the number density of low surface brightness blobs outside of clusters.

246.41 – The Search for Diversities in Clumpy Galaxies

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Contributing teams: UV UDF Team

We present an investigation utilizing the deepest ultraviolet data in the Hubble Ultra Deep Field (HUDF) taken with Wide Field Camera 3 UVIS detector (90 orbits taken with F225W, F275W and F336W filters) during 3 epochs. Preliminary studies using selected galaxies in epochs 1 + 2 (F275W) show disks with clumps indicative of star forming regions. Here we present the analysis of the new epoch 3 data with the F275W band comprised of about 230 galaxies, many of which have a variety of clumps - from single clumps to galaxies littered with clumps. We perform a morphological study of ultraviolet-detected sources at redshifts 0.5 < z < 1.5 in the optical rest-frame. We used a morphological classification scheme similar to that employed by the Hubble CANDELS survey team and find that most of the clumpy objects are disks, followed by irregulars. We calculated both clump sizes and luminosities in the rest-frame UV. We find that the majority of these UV bright clumpy galaxies are classified as Scd and starburst spectral types and have clump sizes between 0.7 to 1.9 kpc.

246.42 – Outflow Properties of Star-forming Galaxies at z~2 from the MOSDEF Survey

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The MOSFIRE Deep Evolution Field (MOSDEF) survey is using the MOSFIRE instrument on the Keck I telescope to obtain more than 1700 rest-frame optical spectra of galaxies from redshift 1.5 to 3.6 over four years. We are using the first 200 spectra to investigate the prevalence of outflows measured in emission in broad components of the nebular emission lines. We create stacks of galaxies based on properties such as star formation rate, stellar mass, and star formation rate surface density (controlling for the presence of AGNs) in order to study how outflow strength depends on these factors. Additionally, we will stack spectra by redshift to understand how outflows change over time. We will present the results of two component (narrow and broad) fits to the nebular emission and compare to theoretical predictions of outflow efficiency.

246.43 – Further Studies of Lyman-alpha Galaxy Halos in MUSYC-LAE Fields

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Contributing teams: MUSYC Collaboration

Lyman alpha emitting galaxies (LAEs) have been found over a vast range of redshift (0.2 - 7), and are the likely progenitors of galaxies like the Milky Way. Since many of these objects are relatively metal-poor and dust-poor, much of their Ly-alpha emission escapes into intergalactic space, and theory suggests that these photons may illuminate the surrounding HI gas. However, detecting this diffuse emission is quite difficult, due to systematic effects associated with image flat fields and the large scale point spread function. In a recent study, we carefully modeled these effects and showed that z=2-3 LAEs in the Extended Chandra Deep Field South (ECDF-S) do not appear to have extended Lyman-alpha emission. However, this may simply be due the region's low density environment, as other studies in denser regions claimed the detection of Ly-alpha halos. In this study, we repeat our search for extended Lyman-alpha halos in two fields previously observed by the MUSYC project: the Extended Hubble Deep Field South (EHDF-S), for which we have data at z ~ 2 and z ~ 3, and SDSS 1030+05, where data exists at z ~ 2. At z ~ 2, both these fields have higher LAE densities than the ECDF-S, with the EHDF-S being over dense by a factor of ~ 1.9 and SDSS 1030+05 being over dense by a factor of ~ 2.5. At z ~ 3, the EHDF-S and ECDF-S have roughly the same LAE densities. We present the amount and spatial extent of the halos detected, and set robust limits on their properties.

246.44 – Parallel Galaxy Main Sequence and Quasar Evolution from z=0-6: A Unified View of Black Hole and Galaxy Evolution?

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Contributing teams: SPLASH

Using new first epoch Spitzer SPLASH data, plus measurements from the literature, we confirm the existence of the star-forming "main sequence" (MS) of star formation rate vs. stellar mass for galaxies out to z~6. We also find a clear agreement with MS results from the literature, which we use to derive a robust functional form for the MS in both time and mass. The results are then compared to SDSS quasar data, where an almost identical time evolution of bolometric luminosity with time and mass is observed. We confirm the existence and evolution of a characteristic "turnoff mass" for MS galaxies, and find that a similarly defined quantity for quasars evolves in a strikingly similar way. We use these results to propose a possible unified framework for joint AGN-galaxy evolution and briefly explore some of the implications.

246.45 – Dynamically Modeling of Major Galaxy Mergers - Testing IDENTIKIT Using GADGET SPH Simulations

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Dynamically modeling galaxy mergers is possible by looking for the most similar simulations to the morphology and and kinematics of data. This similarity is usually subjective and based on the visual comparison between data and the model. IDENTIKIT combines self-consistent and test-particle techniques to utilize relatively rapid exploration of the parameter space in a galactic collision. While in IDENTIKIT 1 user has to search the parameter space to find the best visual match, IDENTIKIT 2 provides a quantitative measure for the quality of match, called "score". Score is calculated based on the number of test particles that reside in user-selected phase-space regions in the tidal features of the galactic encounter. So, in order to find the best model, the user selects these regions and looks for model with the best score. While this method may revolutionize the way we model galaxy mergers, we need to know what are the systematic and random uncertainties in the best fit model.

So, we have used a set of GADGET SPH simulations as fake data. Since we know the correct encounter parameters for our fake data, we can detect systematic biases. We automated the selection of normally user-selected phase-space regions. We explored how different selection of these regions affect the parameters in the best fit model, so the random uncertainties of the best fit model is calculated. We are specially interested in measuring orbital parameters of major galaxy mergers. Based on our preliminary results IDENTIKIT 2 is successful in constraining the eccentricity and the time since pericenter of the encounter. But, the random uncertainties in pericentric distance is quite large.

246.46 – The Effect of Baryons on the Distribution of Dark Matter in Galactic Halos

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We analyze a series of high resolution hydrodynamical simulations performed within the MaGICC (Making Galaxies In a Cosmological Context) project to study the effect of baryons on dark matter distribution. MaGICC galaxies are among the most realistic simulated galaxies available today and therefore offer a unique environment to better understand the back reaction of baryons on dark matter. We consider the effect of baryons on several parameters of the dark matter halo, including the shape, velocity distribution, velocity anisotropy, and the pseudo phase space density. We find that baryons make more spherical dark matter haloes, more tangential dark matter orbits, a more skewed velocity distribution, and a different power law expression for the pseudo phase space density. However, these effects aren't as strong as predicted by previous studies based on galaxies having a non realistic ratio of stellar to dark matter halo mass.

246.47 – Baryon Cycling in Cosmological Simulations of Spiral Galaxies

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The cycling of gas through galactic fountains links disks to halos; simulations enable astronomers to follow this cycling by tracking gas particles. Most previous computational analysis, however, has focused either on low-resolution simulations of many galaxies or on a single high-resolution galaxy. In order to follow gas ejection and reaccretion in galaxies with spatially-resolved disks, we analyzed sixteen spiral and dwarf galaxies from zoom-in cosmological runs integrated to a redshift of zero. These simulations include advanced ISM modeling and metal-line cooling and have appropriate redshift-zero stellar masses, bulge-to-total masses and metallicities. We used them to analyze spatially-resolved gas loss and accretion as a function of halo mass and redshift. We demonstrate the redistribution of baryons throughout the disk and quantify how gas cycling and re-enrichment increases with halo mass.

246.48 – Examining the dark matter distribution of a simulated dwarf galaxy undergoing a merger

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When constructing a theoretical model for the evolution of dwarf galaxies, it is vital to understand how the dark matter distribution changes over a galaxy's lifetime. Previous simulations have demonstrated that supernova-driven outflows can lead to realistic dark matter profiles. However, in order to fully comprehend how dark matter behaves over the course of a galaxy's lifetime, we must study how its distribution changes under extreme circumstances, such as mergers. This is because while mergers lead to a loss of angular momentum, they also cause increased star formation, which drives strong outflow and reduces the central dark matter concentration. In order to study the changes in dark matter distribution during a merger, we analyzed a high resolution, hydrodynamical simulation of a dwarf galaxy with a realistic, cored dark matter profile at z = 0. By examining the star formation rates, gas dispersion, and gas surface density of the galaxy while it underwent a major merger, we were able better understand the baryonic processes that influence the dark matter distribution. Furthermore, evaluation of the dark matter profile both before and after the merger showed a reduction in the central dark matter concentration, with a major decrease in the density coinciding with the merger.

246.49 – galaxy formation and evolution with an improved SPH code

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We present the results with an updated version of Gadget-3. Our improvements over the original version include both modifications on SPH algorithms and physical processes relevant to galaxy formation and evolution. A smoother kernel is

used to reduce the noise of force calculation. Discontinuities and sub-sonic turbulence are treated with a time dependent conduction term and a time dependent viscosity term. The new code successfully handles the KH/RT instabilities. A new set of metal dependent cooling/heating functions is computed self-consistently to account for the ionizing UV background from galaxies and QSOs. Meanwhile we also updated the star formation model and black hole accretion model. With all of these improvement, our code can produce more realistic disk galaxies compared to previous work. Future simulations with this new code will give us more reliable results and enable us to better understand galaxy formation and evolution in greater detail and accuracy.

246.50 – A WISE View of Almost Dark ALFALFA Galaxies

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Dark galaxies are galaxies that have few stars and are made mostly of dense gas. These objects are expected to be difficult to detect with optical telescopes. Dark galaxies are thought to exist possibly associated to tidal interactions between galaxies, or they might represent an early stage in the process of galaxy formation. The prototype for dark galaxies is the southwestern component of HI 1225+01 (Chengalur et al. 1995, AJ 109, 2415) with an HI mass of 8*10^8M™ circular velocity ~34 km/s. The Arecibo Legacy Fast ALFA extragalactic survey (ALFALFA) is a blind HI survey completed in 2012. One of the scientific objectives of ALFALFA was the possible detection of HI tidal remnants (Giovanelli et al. 2005, AJ 130, 2598). Less than 2% of the total extragalactic population of the α.40 Source Catalog from ALFALFA are classified as dark HI sources (Haynes et al. 2011, AJ. 142,170). As part of our participation of the Undergraduate ALFALFA Team we present an analysis of the infrared data from WISE of a sample of the most extreme high M_HI/ almost dark galaxies being studied by the ALFALFA team. Some of these objects have no detectable optical emission in SDSS images, while others may be associated with very faint, low luminosity stellar counterparts. For HI 1225+01, Matsuoka et al (2012, AJ 144,159) obtained an R band image of the NE clump of this object, and also found emission in the Spitzer IRAC bands of 3.6μm and 4.5μm among others. No emission was found In the SW component. We present our findings of the emission at 3.4, 4.6 and 12μm from WISE of a region centered on the almost dark galaxies. This research has made use of the NASA/IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. We gratefully acknowledge the support from the NSF grant AST-1211005 for this project.

246.51 – Very Large Array HI Imaging of ALFALFA-Discovered 'Almost Dark' Galaxies

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We present new pilot VLA HI spectral line imaging of five enigmatic sources discovered by the ALFALFA extragalactic survey. These five targets are drawn from a larger sample of 'Almost Dark' systems that have unusually high hydrogen mass to light ratios. The candidate 'Almost Dark' systems fall into four broad categories: 1) systems that lack a stellar counterpart in moderate-depth optical imaging; 2) systems with very low surface brightness stellar populations; 3) systems with multiple possible optical counterparts; 4) systems with HI in the vicinity of, but offset from, early-type galaxies. The five sources presented here (AGC193953, AGC208602, AGC208399, AGC226178, and AGC233638) include at least one source in each broad category. HI emission is detected in all five systems. We compare the resulting HI total intensity and coarse velocity fields to optical imaging drawn from the Sloan Digitized Sky Survey. These pilot observations set the stage for a major follow-up HI observing campaign that is now underway with the Westerbork Synthesis Radio Telescope. The Cornell ALFALFA team is supported by NSF AST-1107390 and by the Brinson Foundation. The Undergraduate ALFALFA Team is supported by NSF grant AST-1211005. JMC is supported by NSF grant AST-1211683.

246.52 – The Low CO Luminosity of Three Extremely Metal-Poor Star-Forming Galaxies

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We present sensitive observations in the CO J = 1 ? 0 emission line of the metal-poor dwarf irregular galaxies Sextans A, Sextans B, and Leo P, all obtained with the CARMA interferometer. While no confirmed detections of CO emission were found, the proximity of the three systems allows us to place very stringent upper limits on the CO luminosity in metal poor galaxies. We find the CO luminosities to be $L_{CO} < 2270$ K km/s pc^2 for Leo P, $L_{CO} < 6490$ K km/s pc^2 for Sextans B, and $L_{CO} < 8550$ K km/s pc^2 for Sextans A. These are among the most sensitive CO upper limits in metal poor galaxies to date. Comparing the star formation rate to our CO upper limit provides evidence that either the CO to H_2 conversion factor increases sharply as metallicity decreases, or stars are forming in these three galaxies very efficiently, requiring little molecular hydrogen. The Cornell ALFALFA team is supported by NSF AST-1107390 and by the Brinson Foundation. The Undergraduate ALFALFA Team is supported by NSF grant AST-1211005. JMC is supported by NSF grant AST-1211683.

246.53 – The UAT Groups Project: HI Deficiency and Mass Function for Galaxies in Groups

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Contributing teams: Undergraduate ALFALFA Team

We present the HI deficiencies of galaxies in a sample of ten well-studied groups that form a subset of the Arecibo Legacy Fast-ALFA (ALFALFA) survey. We expect the HI content of galaxies in groups to reflect the strong galaxy-galaxy interactions that are likely to take place in these dense, but low velocity dispersion environments; HI gas may, for example, be tidally drawn out, merged with other galaxies, or destroyed in starbursts. We find that, despite strong morphological segregation (with early-type galaxies dominating the centers of the groups) , most late-type massive galaxies near the center exhibit only slightly depressed levels of HI relative to late-type galaxies in the outskirts. Similarly, the HI mass function for these groups is consistent with that for the full ALFALFA survey, despite the clear difference in galaxy populations across environments.

246.54 – Constraints on First-Stars Models From Observations of Local Low-Mass Dwarf Galaxies and Galactic Metal-Poor Halo Stars

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The first metal-free stars in the universe had hard ionizing photon spectra and unique element yields from their supernovae, leaving signatures in the reionization of the intergalactic medium and in the metal enrichment of gas in the early universe. Here, we examine the metal abundances in a variety of systems in the local universe, from very metal-poor Galactic halo stars to ultra-faint dwarf spheroidal galaxies, and compare them with the latest theoretical models of massive stars with and without rotation. We confirm the similar abundance patterns found in the ultra-faint dwarfs and metal-poor halo stars by recent studies, and find new trends of interest in a variety of individual elements spanning metallicity values of [Fe/H] from about -2 to -5. We also compare our results with the abundances found in the very metal-deficient nearby dwarf irregular galaxy Leo P, which was recently discovered in the Arecibo ALFALFA survey. We comment on the similarities and differences between abundance trends in gas-rich dwarf galaxy systems like Leo P versus gas-poor ones like the ultra-faint dwarf spheroidals, and on the possibility of such systems hosting populations of the first stars. This work has been supported by NSF grant AST-1211005 and by Research Corporation through the Cottrell College Science Award.

246.55 – L-Band Wide Follow-up Survey: Interesting Candidates and IDL Routines

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Contributing teams: ALFALFA Team

ALFALFA-U is a collaborative undertaking of faculty and students at 19 institutions, performing research using the ALFALFA blind HI survey and the L-Band Wide (LBW) follow-up survey. The primary goal of the LBW survey is to conduct targeted L-band Wide observations of the most interesting ALFALFA sources. This included the following four categories: 1. dark galaxy candidates, 2. OH Megamaser candidates, 3. extreme gas-dominated dwarf galaxy candidates, and 4. statistical samples of low signal to noise sources associated with optical counterparts. An IDL (Interactive Data Language) routine was

developed to reduce the LBW data, provide integrated fluxes of the signals and calculate RMS noise. There were 312 definite detections and 328 possible detections of 1256 possible sources. This work has been supported by NSF grants AST-1211005 and AST-0725267.

246.56 – Star Formation and Gas Content in the NRGb 168 Galaxy Group

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Contributing teams: ALFALFA Team

We present a study of gas and star formation properties of galaxies in the NRGb 168 galaxy group as part of the collaborative Undergraduate ALFALFA Team Groups Project. The neutral hydrogen content of galaxies in the group is estimated using 21cm emission spectra taken as part of the Arecibo Legacy Fast ALFA survey. Narrow H alpha and broadband R images taken at the .9m WIYN telescope at Kitt Peak National Observatory are then analyzed in order to determine star formation rates as a function of position and neutral hydrogen content in the group. This work has been supported by NSF grant AST-1211005 and AST-0725267.

246.57 – Star Formation and Gas Content in the NRGb 301 Galaxy Group

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Contributing teams: ALFALFA Team

We present a study of gas and star formation properties of galaxies in the NRGb 301 galaxy group as part of the collaborative Undergraduate ALFALFA Team Groups Project. The neutral hydrogen content of galaxies in the group is estimated using 21cm emission spectra taken as part of the Arecibo Legacy Fast ALFA survey. Narrow H alpha and broadband R images taken at the .9m WIYN telescope at Kitt Peak National Observatory are then analyzed in order to determine star formation rates as a function of position and neutral hydrogen content in the group. This work has been supported by NSF grant AST-1211005.

246.58 – Spitzer, Gaia, and the Potential of the Milky Way

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Near-future data from ESA's Gaia mission will provide precise, full phase-space information for hundreds of millions of stars out to heliocentric distances of ~10 kpc. This "horizon" for full phase-space measurements is imposed by the Gaia parallax errors degrading to worse than 10%, and could be significantly extended by an accurate distance indicator. Recent work has demonstrated how Spitzer observations of RR Lyrae stars can be used to make distance estimates accurate to 2%, effectively extending the Gaia, precise-data horizon by a factor of ten in distance and a factor of 1000 in volume. This Letter presents one approach to exploit data of such accuracy to measure the Galactic potential using small samples of stars associated with debris from satellite destruction. The method is tested with synthetic observations of 100 stars from the end point of a simulation of satellite destruction: the shape, orientation, and depth of the potential used in the simulation are recovered to within a few percent. The success of this simple test with such a small sample in a single debris stream suggests that constraints from multiple streams could be combined to examine the Galaxy's dark matter halo in even more detail --- a truly unique opportunity that is enabled by the combination of Spitzer and Gaia with our intimate perspective on the Galaxy.

246.59 – Detection of CO2-1 in an ALMA [CII]-detected galaxy at z = 4.44

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We present CO(2-1) observations of the submillimetre galaxy ALESS65.1 performed with the Australia Telescope Compact Array at 42.3 GHz. A previous ALMA study of submillimetre galaxies in the Extended Chandra Deep Field South detected [CII] 157.74 micron emission from this galaxy at a redshift of z = 4.44. The CO(2-1) emission was detected at the ~4? level, implying a cold gas mass in ALESS65.1 of M_{gas} = 2.3 ± 0.6 × 10^{10} M™. The estimated gas depletion timescale is 70 ± 20 Myr, which is similar to other high redshift SMGs, and consistent with z > 4 SMGs being the likely progenitors of massive red-and-dead galaxies at z > 2. The ratio of the [CII], CO and far-infrared luminosities implies a far-ultraviolet field of G_0 ~ $10^{2.75}$, which is similar to starbursts in the local universe, but on the weak end of local ULIRGs. The observed $L_{[CII]}/L_{FIR}$ = 2.3 × 10^3 is high compared to local ULIRGs and, combined with $L_{[CII]}/L_{CO}$ ~ 2100, is consistent with ALESS65.1 having an

extended (several kpc) [CII] emitting region.

246.60 – Herschel-detected LBGs at z~2

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Lyman-break galaxies (LBGs) are well-known indicators of star formation. By analyzing the dust of moderate redshift (z~2) LBGs, we can further investigate the properties of these strongly star forming galaxies at an epoch when global star formation is expected to peak. Using data observed by Herschel and publicly available via PEP (PACS Evolutionary Probe) and the HerMES (Herschel Multi-tiered Extragalactic Survey) surveys, we derive far-infrared fluxes for our color-selected sample of 73 LBGs in the GOODS-S field. This sample includes a subsample of 14 infrared-luminous LBGs (ILLBGs). Measuring fluxes in the 70, 100, and 160 μm PACS bands, as well as the 250, 350, 500 μm SPIRE bands, we fit modified Planck curves and model spectral energy distributions (SEDs) to make estimations for dust temperatures and masses for our Herschel-detected LBGs.

246.61 – Cosmic evolution of star formation properties of galaxies

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Development of bolometer array and camera at submillimeter wavelength has played an important role in detecting submillimeter bright galaxies, so called submillimeter galaxies. These galaxies seem to be progenitors of present-day massive galaxies and account for their considerable contributions to the light from the early universe and their expected high star formation rates if there is a close link between the submillimeter galaxies and the star formation activities, and the interstellar dust in galaxies is mainly heated by the star light. We review assembly of submillimeter galaxies chosen from the AzTEC and the Herschel SPIRE/PACS data archives, and investigate their spectral energy distribution fits including the data at other wavelengths to deduce details about stellar parameters including star formation rates and parameters yielding the metallicity, composition and abundance in dust, and disc structure of these galaxies. This work has been supported in part by Mid-career Researcher Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology 2011-0028001.

246.62 – Strategies to observe JWST First Light objects at z=10--20 based on recent results from the HUDF XDF.

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Contributing teams: S. H. Cohen, R. A. Jansen (ASU), S. P. Driver, A. Robotham, M. Alpaslan, R. Lange (ICRAR, U-WA), A. M. Hopkins, M. Cluver, I. Konstantopoulos (AAO, Sydney), J. Stuart B. Wyithe, and Robert L. Barone-Nugent (U. Melbourne)

We reflect on the best observing strategies to see an optimum number of First Light objects at z~10-20 with the James Webb Space Telescope (JWST), based on recent results from the Hubble Wide Field Camera 3 UltraDeep Field. First, we summarize the best available data to redshifts z<8 on how the Schechter UV Luminosity Function (LF) evolves in its faint-end slope [alpha(z)], its characteristic luminosity [M*(z)] and corresponding space density [phi*(z)], and use hierarchical models to explore how alpha(z) and phi*(z) may evolve for z>8. We use the strongly declining number of z=9-11 candidates in the HUDF-XDF compared to the large number of z=7-8 objects, to constrain the plausible range in evolution of M*(z) for z>~9. While hierarchical models suggest that alpha(z>8) converges to ~-2 and phi*(z>8) to ~< 10^-3/Mpc^3, the one plausible z~=10-12 candidate seen in the HUDF-XDF suggests that M*(z) may drop to fainter than M=--17.5 mag at z>10 in WMAP9/Planck cosmology. If so, this may have a significant impact on the optimal observing strategies of z>10 objects with JWST. If M*(z) and/or phi*(z) continue to decline significantly for z>9, only deep 200+-hr JWST surveys that reach to AB>31 mag will see a significant number of z>10 objects. Shallow or medium deep JWST surveys that reach to AB<30 mag will not see very many unlensed z>10 objects, since they will generally sample brighter than M* at z>10. Hence, in order to sample the brighter-end of the LF at z>10, and to average over the expected significant cosmic variance at z>10, JWST will either need to observe a larger number (>5) of deep JWST fields, and/or it will need to do a much larger number (>10-20) of medium-deep surveys on gravitational lensing foreground targets. The 6 Hubble Frontier Fields that started in 2013 are excellent lensing targets for JWST. We present a subset of 2400 galaxy groups from the GAMA spectroscopic survey to z=0.4 that have M>10^15 M_o and are sufficiently compact to also be excellent lensing targets for JWST medium-deep surveys of First Light objects at z>10.

247 – The Solar System Poster Session
Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

247.01 – Lightcurve Analysis of Three Asteroids

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We present the lightcurves of three asteroids and preliminary rotation period determinations. The asteroids were chosen by an undergraduate non-major class at the University of Maryland and observed in 2013 October using telescopes in Nerpio, Spain owned by itelescope.net and operated remotely by the students. We would like to thank the Astronomy Department of the University of Maryland for their support in this class.

247.02 – Characterization of Asteroid 9983 Rickfienberg

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Four-color filtered CCD photometry was obtained on 9983 Rickfienberg during its 2013 opposition. High-tempo exposures were taken with the S2KB camera on the 0.9m WIYN telescope at Kitt Peak National Observatory over three nights, covering several rotations of the object. In addition, observations were obtained of a field containing 4 Landolt standard stars, and four other asteroids of known composition (259 Alethia (X type), 453 Tea (S type), 1343 Nicole (C Type) and 2508 Alupka (V type). These data were obtained to confirm that color indices measured for 9983 Rickfienberg could be confirmed and errors bounded. Asteroid 9983 Rickfeinberg exhibed color indices of B-V=0.935 (uncertainty 6.7%), V-R=0.294 (uncertainty 4.88%) and R-I of -0.298 (uncertainty 11.0%). No variation in composition was seen over the period of each rotation within the measurement uncertainties. This work was conducted by undergraduate students from Carthage College, and analysis was performed by students at Phillips Academy. Support was received from the Wisconsin Space Grant Consortium and a Small Research Grant from the American Astronomical Society.

247.03 – Rogue Asteroids in the Inner Main Asteroid Belt

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Very red featureless asteroids (spectroscopic D-types) are common among Jupiter Trojans, Hildas, and the outer main belt, and are thought to have formed in the outer solar system. Dynamical models of planetary migration and orbital drift by the Yarkovsky effect predict these D-types could have been transported as close to the sun as the middle main belt, but not closer. We detect D-types in the inner main belt, where they are not expected, through follow-up observations of 13 D-type candidates as determined by SDSS colors. Near-infrared spectroscopic measurements were taken using SpeX on the IRTF. Known inner belt D-types range in diameter from roughly 7 to 30 kilometers. Based on these detections we estimate there are ?100 inner belt D-types with diameters between 2.5 and 20km. The total mass of inner belt D-types is 4x10^16kg which represents 0.01% of the mass of the inner belt (note Vesta alone accounts for 2/3 of the inner belt mass). Dynamical models have yet to show how D-types could penetrate into the inner reaches of the Main Belt.

247.04 – Capture of Asteroids and Transport of Asteroid Materials to Earth

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Contributing teams: no team

Recently there has been much discussion on the capture of asteroids or mining the asteroids. While the technology might be years away, in this paper we will discuss an energy efficient method to transport either a small asteroid or materials gathered from asteroids to the Earth. In particular, I will concentrate on a large and nearby asteroid, 8 Flora in the Flora Family. Generally, asteroids are located between 2 to 3 AU (astronomical unit) from the Earth, and in transporting materials from asteroids to the Earth, an energy equivalent of the gravitational potential energy difference between the Earth and the asteroids to the Sun. This amount of potential energy is a sizable fraction of the orbital kinetic energy of the Earth around the Sun. This amount of energy is considerable. In this paper I propose to use the planet Mars as a medium to remove much of the gravitational energy difference. In the case of the asteroid 8 Flora, it is only necessary to decelerate the asteroid materials by a small decrement, of the order of 3 km/sec. This decrement could even be achieved (pending on the availability of technology) by mechanical devices such as catapults on 8 Flora. It is also proposed to separate a pair of contact asteroid binaries by using impulse propulsion, and to propel one component of the separated asteroids to pass by Mars to be

decelerated to reach the Earth orbit and captured by the Earth or the Moon. The plausibility of this ambitious project will be discussed. The author is NASA-GSFC Astrophysicist, Retired.

247.05 – A Troop of Trojans: Photometry of 24 Jovian Trojan Asteroids

Linda M. French[1], Robert D. Stephens[2], Daniel Coley[2], Lawrence H. Wasserman[3], Daniel La Rocca[1], Faith Vilas[4]

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Because of their greater distance from the Sun, the Jovian Trojans have been less studied than main belt asteroids. Although they are numerous (nearly 6000 have well determined orbits as of July 2013), the Trojans remain mysterious in many ways. Their spectra are unlike those of any meteorites in terrestrial collections. The spectra and the low albedos of Trojans, however, bear a strong resemblance to those of cometary nuclei (Abell et al. 2005; Fornasier et al. 2007; Emery et al. 2011). The Nice Model (Morbidelli et al. 2005; 2009) predicts that the Trojans may well be objects that originated with today's Kuiper Belt Objects. The rotation of asteroids larger than ~50 km in diameter seems to be determined largely by collisions, while that of smaller bodies is shaped primarily by YORP forces and torques (Pravec et al. 2008). We are surveying the rotation properties of Trojans to see whether similar trends are present. We find an abundance of slow rotators, including the first documented tumbler among the Trojans. We present 24 new Trojan lightcurves (French et al. 2013), mostly from objects ranging from 30-50 km in diameter, as well as more recent observations. We also discuss observations of five sub-20 km Trojans, whose rotation properties are consistent with cometary densities.

247.06 – Identification and Investigation of Martian Dust Source Regions from Orbital Observation

Laura Kulowski[1], Huiqun Wang[2]

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We have constructed a database of locations of active dust lifting on Mars from existing Mars Daily Global Maps (MDGMs). The daily global maps used in this study were generated from wide-angle images taken by the Mars Orbiter Camera (MOC) on Mars Global Surveyor (MGS) (Mars Years 24-27, July of 1999 to January of 2005). We concentrated on the "equatorial map" (60°N-60°S) and the periods without global dust storms. Areas of active dust lifting in each MDGM were visually identified based on an analysis of albedo changes, color, and morphology. Using this database, we assess the spatial, temporal, and size distribution of lifting areas and classify lifting events by structure. Lifting is found to be concentrated in three seasonal windows: Ls = 0°-80°, Ls = 130°-230°, and Ls = 260°-360°. Large-scale lifting mainly occurs in the Ls = 130°-230° seasonal window. Northern and southern lifting events also have preferred seasonal windows of occurrence, with northern ones concentrated during Ls = 180°-230° and Ls = 280°-360° and southern ones concentrated during Ls = 20°-60° and Ls = 130°-220°. Both annually and for the identified seasonal windows, the number of small lifting events far exceeds the number of large ones. Observations indicate that active dust lifting is most frequently observed in the Arcadia, Acidalia, Argyre, and Hellas regions while inactive regions include Tharsis, Arabia Terra, and sections of Elysium. These locations correspond well with General Circulation Model (GCM) predicted annual surface wind stress and dust deposition distributions. In our analysis, three morphological categories for active dust lifting are defined: puffy, pebbled, and plume. We demonstrate that these structures are apparent in all seasonal windows. Our data also suggests that pebbled and plume morphologies occur at similar latitudes and times of the year. Puffy structures are differentiated from pebbled and plume structures in that they occur more frequently at lower latitudes. This work is supported by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851, the Smithsonian Institution, and the NASA MDAP program.

247.07 – Extraction of Thermal Spectra of the Four Large Satellites of Uranus

Paul Zivick[1], Vianney Lebouteiller[2], Jonathan I. Lunine[2]

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The present interest in a Uranus orbiter has refocused attention on the distant planet's mysterious moons. The latter form a regular satellite system whose evolution - during and after the event that tilted Uranus' pole - is poorly understood. Near-infrared observations of the moons have been analyzed, but the mid-infrared (MIR) range remains relatively unexplored and could provide additional insight into the composition of the surfaces and the chemistry occurring thereon. Such MIR spectra cannot be collected from the ground and require spacecraft or high altitude aircraft. We present here data of Ariel, Umbriel, Titania, and Oberon, obtained by the Infrared Spectrograph (IRS) aboard the Spitzer Space Telescope during its cold mission. We developed a state-of-the-art technique to extract the mid-infrared spectra of the moons, making use of the Spectroscopic Modeling Analysis and Reduction Tool (SMART). The observations of the moons were affected by stray light

from the planet reaching the detector, making this dataset obtained in 2005 too difficult to tackle until now. To disentangle the light contributions from the moon and the planet's stray light, we generated theoretical point spread functions (PSF) using Spitzer Tiny Tim (STINY_TIM). We then calculated the effective, expected, normalized contributions from the moon's and planet's PSFs inside the slit. Finally, we used a multiple linear regression to extract the moon and planet fluxes simultaneously, for each wavelength element. These first MIR spectra of Uranus' moons are now being examined for molecular features and blackbody temperatures. Preliminary results show the lack any molecular absorption features, in particular CO2. The inferred temperatures are in complete agreement with the theoretical models. Implications for future observations with JWST will be discussed.

247.08 – Observation and Analysis of a Single-Chord Stellar Occultation by Kuiper Belt Object (50000) Quaoar

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The Williams-MIT collaboration (www.stellaroccultations.info) predicted and observed a stellar occultation of 2UCAC 26260847 (mag 14.35) by KBO 50000 Quaoar (mag 18.9) on 8/9 July 2013. Observations were attempted from a total of five sites in Chile, Venezuela, and Massachusetts. Only one site, Llano del Hato National Astronomical Observatory in Venezuela, had a positive detection of the occultation, giving us a single chord on Quaoar. All other sites were cloudy. The light curve from the 8/9 July 2013 event has been analyzed with the assumption that Quaoar is ellipsoidal or spherical, placing bounds on some of Quaoar's properties: diameter (> 1138 ± 25 km), density (< 1.82 ± 0.28 g cm^{-3}), and albedo (< 0.14 ± 0.10). An independent prediction of the occultation's shadow path by Fraser, Gwyn, et al. (2013) suggests that the chord is near-equatorial, which means that our bounds on Quaoar's properties are closer to estimates. We will compare our result with that of the 11 February 2011 single-chord occultation detected by Sallum et al. (2011) and Person et al. (2011). A subsequent attempt to observe a second Quaoar occultation, that of 12/13 July 2013 in South Africa, failed because of cloudy weather. This work was supported in part by NASA Planetary Astronomy grants NNX08AO50G and NNH11ZDA001N to Williams College, NNX10AB27G to MIT, and USRA grant #8500-98-003 to Lowell Observatory. We thank Steven P. Souza at Williams, and other collaborators in planning and carrying out the various observations: including Libardo Zerpa, Joresly Villarreal, Richard Rojas, and Jorge Moreno at Llano del Hato, and Patricio Rojo and Matias Jones at Cerro Calan/U. Chile.

247.09 – Variable Features of Saturn's B-ring

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Using a combination of measured observables, we analyzed the features of B3 region of Saturn's rings for possible patterns. The B3 region of Saturn's rings ranges from 104000km-110500km and is the most opaque portion of the B-ring. The B3 region is characterized by a median optical depth of ~3.6, the highest for any region of Saturn's rings (Saturn from Cassini-Huygens Colwell et al). Many astrophysical systems are disk-shaped, but are not accessible for in depth study. The rings of Saturn provide an ideal laboratory to study disk dynamics because of its accessibility. In particular, the B-ring is interesting because it is the densest and most optically thick ring we have access to. While this region is almost completely opaque, there are several places where there are small increases in the amount of transmission detected by stellar occultation. Some of the features remain in a relatively constant location whereas other vary over time. We began by quantifying the features and then looked for patterns in the features. Two of the main features appear in proximity to resonances of Saturn's moons, but the others have no such explanation. For our analysis, we used data from twelve Gamma Crucis occultations taken in 2008 with the VIMS instrument on the Cassini orbiter. The data were taken at 2.92 microns. To quantify the features, we first calculated the equivalent width and weighted mean radius for each feature. We then extrapolated these observables to look for various types of pattern speeds, and looked for any underlying patterns that might explain the source of the features.

247.10 – Applying Advection-Corrected Correlation Image Velocimetry techniques to Saturn's winds

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Using image data taken from Cassini, we have applied Advection-Corrected Correlation Image Velocimetry (ACCIV) to wind flows in Saturn's atmosphere. ACCIV intelligently evolves and matches features in between large time separated images, enabling extraction of high accuracy wind velocities, even in the case of non-optimal data. We use these results to construct a model of Saturn's atmospheric dynamics.

247.11 – Geolocation of Terrestrial Gamma Ray Flashes in Gamma Rays Using the Fermi Large Area Telescope

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We derive geolocations of bright Terrestrial Gamma ray Flashes (TGFs) directly in gamma rays using the Fermi Large Area Telescope (LAT) and compare with geolocations derived from LF and VLF (radio) networks. Imaging of the gamma ray direction is made possible by the fine spatial resolution of the LAT instrument, which is intended to make maps of the high-energy gamma ray astrophysical sky. Simulations show that LAT can geolocate very bright TGFs in favorable geometries with accuracies of several tens of km. Recent work by Connaughton et al. (2013) strongly suggests that the broadband radio signal is produced by the same bulk flow of relativistic electrons that create the gamma ray signal through bremsstrahlung interactions in the atmosphere. Our analysis confirms this picture by establishing that the radio and gamma ray signals are both temporally and spatially coincident. This work was performed at NRL and sponsored by NASA DPR S-15633-Y.

247.12 – Infrared Spectroscopy of Comet C/2012 S1 (ISON)

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Comet C/2012 S1 (ISON) provided a rare opportunity to study the dust characteristics of a dynamically new comet on a sungrazing orbit. Entering the inner solar system for the very first time, its surface layers have experienced little processing from solar irradiation. Its expected close passage of the Sun should remove a substantial amount of surface material, revealing the inner material stored for billions of years inside the nucleus. Here we present infrared spectroscopy of ISON, obtained with NASA's Infrared Telescope Facility. This work was supported in part by the IR&D program at The Aerospace Corporation.

247.13 – Pilot Study of Enhanced Minor Planet Detection Using NEOWISE Data

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The solar system science component of NASA's Wide-field Infrared Survey Explorer (WISE), known as NEOWISE, extracted detections of more than 158,000 asteroids and comets, including 34,000 new discoveries. These objects were detected through a search algorithm that actively rejected inertially fixed sources such as stars and galaxies and selected candidate moving objects through the construction of position-time pairs known as tracklets. A minimum of five detections were required in order to construct a tracklet; this system enabled the discovery of new minor planets as well as detection of previously known objects. However, many more asteroids are potentially recoverable in the NEOWISE data, such as objects that failed to appear in five or more images. Stacking of objects with well-known ephemerides at the observational epoch has allowed for the recovery of many objects that fell below the single-frame detection threshold. Additional objects were recovered by searching the NEOWISE source lists for objects that appeared fewer than five times in single frames. We

present the results of a pilot study that has allowed for the recovery of minor planets from the NEOWISE data using both techniques, resulting in the derivation of diameters and albedos for the sample. This pilot study will be extended to the entire catalog of known minor planets by the NEOWISE project in the near future.

247.14 – MCMC Radiometric Diameter Uncertainties Applying a Rotating Cratered Thermophysical Model to WISE Data

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Thermophysical models have many parameters that cannot be determined using infrared observations at a single epoch. But by varying these parameters using a Monte Carlo Markov chain with reasonable prior distributions one can determine the uncertainties in the radiometric diameters introduced by the poorly known parameters: typically the rotation pole and the dimensionless thermal inertia parameter. This MCMC approach has been applied to several asteroids observed by WISE: 2010 AB78, a NEO observed by WISE in 3 epochs, has a well determined rotation pole and a diameter 1.28 +/- 0.03 km with 3 percent precision; 2010 CK9, an MBA observed by WISE in one epoch, has a diameter of 3.46 +/- 0.21 km with 6 percent precision; and 2010 MU112, a very hazardous asteroid with a MOID of 0.0011 AU, C3 = 869 km^2/sec^2, a diameter of 611 +/- 84 meters for 14 percent precision from one WISE epoch at phase angle 62 degrees. The proposed NEOcam mission will achieve a long lifetime using passive cooling and obtain many epochs of IR data on most NEOs, allowing the determination of rotation poles, thermal inertias, and diameters with good precision.

247.15 – The Pre-Perihelion Size of the Nucleus of Comet C/2012 S1 (ISON)

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Contributing teams: HST ISON Imaging Science Team

Comet C/2012 S1 (ISON) is so-far the only dynamically new comet known to have a sungrazing orbit. The comet was discovered more than a year before its November 2013 perihelion, which is at a distance of 1.7 solar radii from the surface of the Sun. Such a short perihelion distance causes an extremely high erosion rate, which could effectively erase the previous surface, revealing an interior unaffected by any surface processing that occurs during residence in the Oort cloud. Initial expectations were that the comet would be near naked-eye visible at 1 AU, as well as close to the Sun. Because of this rare opportunity, an observing campaign was started by the community to study comet ISON, both before and after perihelion. As part of this campaign, we obtained Hubble Space Telescope (HST) Wide Field Camera 3 images designed to characterize the nucleus and inner-coma. Here, we report on our efforts to estimate the effective radius of the nucleus by fitting the images with a model point source and coma. Our first data were taken on 10 April 2013, when the comet had a heliocentric distance of 4.15 AU, a geocentric distance of 4.24 AU, and a phase angle of 14 deg. We place an upper limit of 2 km on the nucleus radius, which we compare to other size estimates. We also examine a second set of images, expected to be taken with HST in October 2013.

247.16 – Observations of the Black-Drop Effect at the 2012 Transit of Venus

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We observed the 2012 transit of Venus from several locations, including the Mees Solar Observatory of the University of Hawaii on Maui; the Dunn Solar Telescope at the Sacramento Peak Observatory of the National Solar Observatory in Sunspot, NM; and the Big Bear Solar Observatory of the New Jersey Institute of Technology in California. Our observations, mainly directed at the study of Venus's atmosphere, also included high-resolution views of the black-drop effect. Historically, the black-drop effect proved to be a daunting anomaly for measuring the path length of Venus across the Sun's surface with sufficient time accuracy to allow satisfactory measurement of the astronomical unit. Therefore, this phenomenon set back the accurate calculations for centuries of the size and scale of the solar system. In this paper, we discuss data taken with the New Solar Telescope at the Big Bear Observatory and with the IBIS on the Dunn Solar Telescope. We show the evolution of isophotes as a function of time to demonstrate various limb effects during second and third contacts. Schneider, Pasachoff, and Golub (Icarus 168. 249-256, 2004) have shown that the black-drop effect as seen in a transit of Mercury resulted from both the point-spread function of the telescope and the extreme limb-darkening effect at the region of the solar limb where the black-drop effect is demonstrated, and the current paper extends the analysis to the recent transit of Venus. As they showed, and as is verified here, Venus's atmosphere plays no role in the black-drop effect. ZR (Vassar '14) was a Keck Northeast Astronomy Consortium Summer Fellow at Williams College, supported by an NSF/REU grant to the Keck

247.17 – Interpreting the Thermal Lightcurve of Iapetus at 1.3mm

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Saturn's moon Iapetus is distinguished by a clearly defined hemispherical difference in albedo, ranging from 0.03-0.6. This makes it a unique object for re- solving a thermal light curve, because of how flux varies with respect to longitude. By using continuum data from the Submillimeter Array at 1.3 mm and 230 GHz, flux measurements of 0.0688 Jy (bright side) and 0.0899 Jy (dark side) were obtained. A 38-day observation window allowed for the highest contrast in albedo. By converting flux to brightness temperature via Planck's Law and assuming a standard spectral emissivity value of 0.9, surface temperatures were derived. The darker hemisphere has a surface temperature of 91.899K with ?1 = 3.916 and ?3 = 11.746, while the bright hemisphere has a temperature of 63.939K with ?1 = 1.134 and ?3 = 3.429. This temperature difference at 1.3mm verifies the thermal dichotomy in the subsurface of Iapetus.

247.18 – Lunar Sodium and Potassium Exospheric Emissions

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We report on high-spectral resolution sodium and potassium lunar exospheric data. Observations were taken off the bright limb with a 3 arcmin (~350 km) field of view using a double etalon Fabry-Perot spectrometer at the National Solar Observatory McMath-Pierce Main telescope. Preliminary results show the sodium line width is dependent on lunar phase angle with the widest widths occurring around full moon, i.e., the moon in the Earth's magnetotail region. Interpreting the line width as temperature indicates the sodium to be ~3000K (near full moon) to 1200K (near 1st or 3rd quarter). During the full moon full period in May 2013, we made a direct comparison of sodium and potassium emission. The potassium line width appears to be wider than the sodium emission near 1st and 3rd quarter, but unlike sodium near full moon the potassium emission vanishes. Additionally, we will report on our first ground-based observations in support of the Lunar Atmosphere and Dust Environment Explorer (LADEE) taken starting during the full moon November 2013.

247.19 – January and February Meteor Showers Detected by CAMS: the Cameras for Allsky Meteor Surveillance

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Many meteor showers are in need of validation. Of 493 meteor showers listed in the IAU Working List of Mete-or Showers, only 95 are established. Of the rest, it is uncertain whether they exist or not. The goal of the Cameras for Allsky Meteor Surveillance (CAMS) project in California is to validate or remove the remaining 325 showers. CAMS scales up the use of low-light-level video for meteor triangulation, by deploying 60 video cameras spread over three sites. Once the video data has been analyzed, showers can be confirmed by comparing arrival time, direc-tion of the radiant, and speed of the individual meteors. Once established, showers can be linked to their parent bod-ies and meteoroid streams. The CAMS stations are located in Sunnyvale, at Fremont Peak Observatory, and at Lick Observatory, to the south and east of Sunnyvale, respectively. Each station contains 20 low-light-level security cameras arrayed to view the entire sky above 30°. During the night, the video data from the cameras is written to disk and analysed in day-time with the MeteorScan software package to find moving objects. Eight-second video sequences are saved for all detections. The video sequences are combined at the SETI Institute, where astrometric calibration files are generated and meteors detected from at least two stations simultaneously are found interactively using the Coincidence program. Coincidence also calculates the radiant and velocity of each meteor. Here, we discuss results obtained in January and February 2013. Over 7,500 meteor orbits were cataloged in this period. This outcome doubled the detection rate from the previous two years of CAMS data.We will present graphs of the detected meteor showers and discuss their parent body sources.

247.20 – Explanatory Supplement to the Astronomical Almanac (3rd Edition)

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Publications and software from the the Astronomical Applications Department of the US Naval Observatory (USNO) are used throughout the world, not only in the Department of Defense for safe navigation, but by many people including other navigators, astronomers, aerospace engineers, and geodesists. Products such as The Nautical Almanac, The Astronomical Almanac, and the Multiyear Interactive Computer Almanac (MICA) are regarded as international standards. To maintain credibility, it is imperative that the methodologies employed and the data used are well documented. "The Explanatory Supplement to the Astronomical Almanac" (hereafter, "The ES") is a major source of such documentation. It is a comprehensive reference book on positional astronomy, covering the theories and algorithms used to produce The Astronomical Almanac, an annual publication produced jointly by the Nautical Almanac Office of USNO and Her Majesty's Nautical Almanac Office (HMNAO). The first edition of The ES appeared in 1961, and the second followed in 1992. Several major changes have taken place in fundamental astronomy since the second edition was published. Advances in radio observations allowed the celestial reference frame to be tied to extragalactic radio sources, thus the International Celestial Reference System replaced the FK5 system. The success of ESA's Hipparcos satellite dramatically altered observational astrometry. Improvements in Earth orientation observations lead to new precession and nutation theories. Additionally, a new positional paradigm, no longer tied to the ecliptic and equinox, was accepted. Largely because of these changes, staff at USNO and HMNAO decided the time was right for the next edition of The ES. The third edition is now available; it is a complete revision of the 1992 book. Along with subjects covered in the previous two editions, the book also contains descriptions of the major advancements in positional astronomy over the last 20 years, some of which are described above. Extensive references to online information are given. This paper will discuss this latest edition of the Explanatory Supplement.

247.21 – The Astronomical Almanac: Recent Improvements to a Standard Resource

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The Astronomical Almanac traces its roots to the American Ephemeris and Nautical Almanac, first published in 1855. It is required by U.S. code and considered to be a worldwide standard source for astronomical data. The tabulated positions for solar system objects, standard lists of stars, and associated data have served as a relevant resource for high-precision astronomical applications throughout the changing landscape of astronomical research. A joint publication between the Nautical Almanac Office at the U.S. Naval Observatory and Her Majesty's Nautical Almanac Office in the UK, The Astronomical Almanac requires coordinated research and development for the publication to continually serve as a standard. Updates to the publication are driven by recently passed IAU resolutions, newly available data, or improved astronomical constants. Algorithms for computing the data are also frequently improved. We describe some recent improvements to the publication, including use of JPL's new DE430 planetary ephemeris, the calculation of physical ephemeris quantities for the planets (telescopic appearance of the planetary disks and primary planetary reference points) and updates to the standard lists of stars and celestial objects.

247.22 – Prediction and Archival Tools for Asteroid Radar Observations

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The Earth-based radar facilities at Arecibo and Goldstone have provided very powerful tools for characterizing the trajectories and physical properties of asteroids. This is especially important for near-Earth asteroids (NEAs) (perihelion distance < 1.3 AU) which are important in the context of hazard mitigation and resource utilization. Over 10,000 NEAs have been identified (https://www.iau.org/public/themes/neo/nea/) and over 400 have been detected with radar (http://radarastronomy.org). Both of these numbers are growing rapidly, necessitating efficient tools for data archival and observation planning. The asteroid radar database hosted at radarastronomy.org keeps track of all radar detections, documents NEA physical properties, and provides NEA observability conditions. We have integrated a number of tools with the database to facilitate recordkeeping and observation planning. First, a geometry finder program allows us to identify the optimal times to observe specific NEAs and to compute rise-transit-set windows. Second, a python-based signal-to-noise (SNR) tool allows us to compute SNR values for both Arecibo and Goldstone observations. SNR is dependent on asteroid properties (size, spin, reflectivity), geocentric distance, and telescope parameters. Finally, python-based graphical tools help visualize the history of asteroid detections.

248 – Lenses & Waves Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

248.01 – Using Variability to Search for Lensed Quasars in the Dark Energy Survey

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Contributing teams: Dark Energy Survey Collaboration

The Dark Energy Survey (DES) has just started its first season of a 5 year program using the DECam instrument on the Blanco 4m telescope at CTIO. Over the course of the 5 year survey we expect to discover about 120 lensed quasars brighter than i=21, including 20 high information-content quads (third brightest image required to be i<21). Strongly lensed quasars can be used to measure cosmological parameters. The time delays between the multiple images can be measured via dedicated monitoring campaigns, while the gravitational potential of the lensing galaxy and of structures along the line of sight can be modeled and measured using deep high resolution imaging and spectroscopy. The combination of these observables enables a distance, known as the time-delay distance (a combination of angular diameter distances) to be measured, which in turn can be converted into a measurement of cosmological parameters including those describing the Dark Energy equation of state. The first step in this measurement is to identify the lensed quasars. Traditionally, quasar candidates have been identified by their blue u-g color which allows them to be separated from the much more numerous stellar contaminants. However, the Dark Energy Survey does not take data in the u-band so other techniques must be employed. One such technique is based on the instrinsic variability of quasars (Schmidt et al, 2010, ApJ 714 1194). We have simulated what we would expect for the DES observing cadence in the first two seasons where we expect four visits to a given patch of sky spread over the two years. We will show results from the simulations as well as a first look at the data from the Science Verification phase of DES.

248.02 – Modelling Gravitational Microlenseing Events from Large Scale Surveys: Point-like to Planets

Ben Tunbridge[1,2], Rosanne Di Stefano[1], Frank Primini[1], Idan Ginsburg[1], William Bryk[3], Max Murphy[1], Antonia Oprescu[1], Nikhil Kunapuli[4]
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Gravitational microlensing surveys presently discover ~2000 candidate lensing events per year yet only a small fraction of these are studied in detail, primarily those thought to be likely candidates for exoplanet discovery. We present the results of a comprehensive study in which we use theoretical models to fit the light curves of all microlensing candidates discovered during the 2013 observing season. Our models include the effects of lens binarity, including planetary companions. We also consider source binarity, as well as parallax and the blending of light from the lensed source with light from the lens. In addition we have found that there are cataloged counterparts to ~10%-20% of the events. We therefore use the colors and magnitudes relations of the counterparts to constrain the lensing model. This is the first large and comprehensive study to attempt detailed modeling of lenses, from point-like lenses to binaries and planets. To conduct this work, we developed tools that can be applied to ongoing events during future observing seasons, thereby increasing the rates at which we discover binaries and exoplanets.

248.03 – A framework for modeling line-of-sight effects in strong gravitational lensing

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In strong gravitational lens systems, the light bending is usually dominated by one main galaxy but may be affected by other objects along the line of sight (LOS). Perturbers projected far from the lens can be approximated with convergence and shear, but perturbers projected closer to the lens create higher-order effects and need to be treated individually. We present a theoretical framework for multi-plane lensing that can handle an arbitrary combination of planes with shear/convergence and planes with higher-order terms. We test our framework first using simulations with a single perturber to study where the shear approximation is not valid and where non-linear effects are important. We show that perturbers behind the lens galaxy can be treated as an effective shear in the main lens plane, but perturbers in front of the lens cannot be mimicked by such a shear. Applying this to realistic fields, we find that our LOS framework can reproduce the fitted lens properties and the Hubble Constant, H0, without bias and with scatter that is smaller than typical measurement uncertainties.

248.04 – Laying the Foundation for Space-based Gravitational Wave Detection: LISA Pathfinder, the LISA Test Package, and ST7-DRS

James Thorpe[1], John Ziemer[2], Paul McNamara[3]
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Contributing teams: LPF Team, LTP Team, ST7-DRS Team

Efforts to develop space-based observatories of gravitational waves such as the long-standing Laser Interferometer Space Antenna (LISA) effort or the more recent eLISA effort under consideration for ESA's next large space mission, have traditionally been praised for their scientific potential and criticized for their technological readiness. The LISA Pathfinder (LPF) mission is a dedicated technology demonstrator for such missions. Led by ESA and a consortium of European national agencies and with a minority contribution from NASA, LPF will demonstrate several key technologies for the LISA concept. LPF includes two scientific payloads: the European LISA Technology Package (LTP) and the NASA-provided ST7-DRS. The mission will place two test masses in drag-free flight and measure the relative acceleration between them. This measurement will validate a number of technologies that are critical to LISA-like gravitational wave instruments including sensing and control of the test masses, drag-free control laws, micro-Newton thrusters, and picometer-level laser metrology. LPF is currently in the late stages of integration and test and is planned to launch in 2015. We will present the current status of the LISA Pathfinder mission and the LTP and ST7-DRS payloads as well as the expected impact on the larger gravitational-wave effort.

248.05 – Calculations of Null Geodesics in the Schwarzschild Metric

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This past summer, I received an NSF-REU grant to conduct research on the topic of gravitational lensing. This work was motivated in part by its applications in astronomy; a quantitative understanding of gravitational lensing is essential for astronomers to make accurate astronomical measurements. Our goal for this project was to analyze the motion of light near a massive object such as a black hole or galaxy. This was accomplished by solving the null geodesic equations in Schwarzchild spacetime. In this poster, I present a brief overview of elementary manifold theory and differential geometry, in addition to the solution to the geodesic equation. Although geodesics are the simplest geometric objects, we conclude from this work that they provide valuable insight into the geometry of 4-dimensional spacetime.

248.06 – Optical observations of lensing candidates for millimeter-wave sources

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The field of observational cosmology has taken great strides forward with the development of large aperture, ground-based telescopes that can perform large area surveys in millimeter wavelengths, such as the South Pole Telescope (SPT) and the Atacama Cosmology Telescope (ACT). These instruments have provided astronomers with a new window on the distant universe, from the Cosmic Microwave Background to more nearby active galaxies and dusty star forming galaxies. Recently it was found that a significant subset of the millimeter sources discovered in the new surveys are magnified by foreground galaxies or galaxy clusters acting as gravitational lenses. Therefore, finding and measuring the properties of these lenses is an important aspect of millimeter observing, and a critical step is to obtain their spectroscopic redshifts. We identified 6 lensing candidates for sources observed in an SPT survey using optical imaging data from the Blanco 4-meter telescope. These were then targeted for spectroscopic observations using the Southern African Large Telescope (SALT) from late 2011 to early 2013. From these data we were able to determine the redshift of each candidate, obtaining a range of values from z=0.14 to z=0.80. This project was funded by a grant from the National Science Foundation (PHY-1263280) under the Research Experiences for Undergraduates (REU) program to Rutgers University.

248.07 – Seeking fast transient counterparts to gravitational triggers from LIGO & Virgo

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Contributing teams: LIGO Scientific Collaboration, Virgo Collaboration

During the last science run of initial LIGO and Virgo, a world-wide collection of optical, radio, and X-ray telescopes responded to low-latency gravitational wave triggers, searching for counterparts to possible gravitational wave sources. Upgrades to the major gravitational wave observatories are currently in progress, and are expected to make detections of gravitational waves

from compact object mergers a reality in the next few years. In addition to gravitational waves, a merger of two neutron stars likely produces transient emission across the EM spectrum, including gamma-ray bursts and kilonovae. This poster will present recent progress towards finding fast transient counterparts to gravitational wave sources.

248.08 – Electromagnetic Counterparts to massive black hole mergers

John G. Baker[1]
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We report on numerical relativity studies exploring the possibility of electromagnetic (EM) counterparts to gravitational-wave emitting supermassive black hole (BH) mergers. If these cataclysmic events can be detected and characterized, they promise to be invaluable tools for studying cosmic evolution and high-energy astrophysics in the most extreme environments in the universe. Our simulations apply general-relativistic magnetohydrodynamics (GRMHD) to study magnetized plasma coupled to full numerical relativity simulations of merging BHs. Simulations indicate significant amplification of the initial magnetic field, which could naturally lead to a very powerful EM signature. We report on radiation transport calculations to estimate the characteristics of these signals and discuss dependencies on initial conditions.

248.09 – Pulsar Timing Data Simulator for the testing of Gravitational Wave Analysis Pipelines

Jing Luo[1,2], Fredrick Jenet[1], Scott M. Ransom[4], Paul Demorest[4], Joseph Lazio[3], Yan Wang[1]
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We are developing a new pulsar pulse time-of-arrival simulator based on SPICE, the solar system ephemeris software package provided by NASA's Jet Propulsion Laboratory. Recently, the simulation and analysis of pulsar timing data has been predominately carried out using either the TEMPO or TEMPO2 software packages. This TEMPO -independent simulation will enable full end-to-end testing of the data analysis packages which includes the pipe-lines for detecting and studying gravitational waves.It also has the capability of transforming to a new pulsar time data analysis package. This poster describes the design of the new package and the current status.

248.10 – Limiting alternative theories of gravity with multi-messenger gravitational wave observations

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1. CIERA/Northwestern University, Evanston, IL, United States. 2. Utah State University, Logan, UT, United States.

The advent of gravitational wave astronomy provides new proving grounds for testing theories of gravity. Recent work has reinvigorated the study of bimetric theories of gravity and massive gravity theories. One of the most interesting predictions of these theories is the subluminal speed of propagating gravitational waves. Multi-messenger astronomy provides a unique opportunity to put limits on the difference between the propagation speed of electromagnetic and gravitational waves from these sources. This paper considers two multi-messenger cases: first, the limits from ultra-compact binaries that will be visible to a low-frequency space-based gravitational wave observatory like LISA, and second the limits from isolated pulsars based on the current best limits from LIGO on gravitational wave emission. The required phase comparison between the electromagnetic signal and the gravitational wave signal is derived, and assuming a null result in that comparison, the current bounds on emission are used to place limits on alternative theories that exhibit propagation delays.

248.11 – Creating A Robust And Efficient Pipeline For Detection Of A Gravitational Wave Stochastic Background For Pulsar Timing Data

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The steadily improving sensitivity of pulsar timing arrays suggests that gravitational waves from a stochastic background will be detectable sometime during the next decade. Here a robust and efficient end to end bayesian pipeline for the detection and characterization of the stochastic gravitational wave background will be presented.

248.12 – Recovering Hardware Injections in LIGO S5 Data

Ashley Disbrow[1], Jonah Kanner[2], Roy Williams[2], Michele Vallisneri[3,2], Alan J. Weinstein[2]
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Pasadena, CA, United States. 3. Jet Propulsion Laboratory, Pasadena, CA, United States.

The LIGO Scientific Collaboration will release to the public the LIGO archival data set, which contains data taken at design sensitivity from 11/2005 through 10/2007. The LIGO Open Science Center will provide online access to this data, as well as documentation and tools to guide the user through working with it. In preparation for next year's release, we create and document a worked-out example of accessing and analyzing the LIGO Open Data Set to search for compact-binary-coalescence signals. We also create updated documentation characterizing hardware injections, which are compact-binary-coalescence signals physically injected into the data using magnetic actuators on detector mirrors. Our search generates compact-binary-coalescence templates using well-modeled waveforms and performs a matched-filter search to identify hardware injections. We test for accuracy by comparing the signal-to-noise ratio expected according to documentation created during data collection to the signal-to-noise ratio we recover using our search. We are able to recover the vast majority of the 1492 injections marked as successful. Through our search, we also identify and characterize injections that are not recovered with the expected signal-to-noise ratio, and we update the injection documentation to reflect our findings.

248.13 – eLISA: A mission to study the entire universe with gravitational waves

Martin Hewitson[1]
1. AEI Hannover, Hannover, Niedersachsen, Germany.
Contributing teams: eLISA Consortium

Observing the gravitational universe has been a major goal of the scientific community for the last few decades. Through the direct observation of gravitational waves, we will be able to study the formation of black holes at redshifts are large as 20, track the history of black hole mergers through the various stages of galaxy evolution, detect deviations from the expected behaviour of the Kerr-metric of General Relativity, probe the properties of ultra-compact binaries within our Milky Way, and look for stochastic signals associated with the very beginnings of our Universe. This richness of signals in the millihertz region of the gravitational wave spectrum can be observed with a dedicated space-based gravitational wave observatory, such as the eLISA mission proposed for ESA's upcoming L2/L3 mission slots. This presentation will review the rich science associated with the proposed eLISA mission, and will outline the mission concept and instrumentation needed to open this new window on the gravitational universe.

248.14 – A new torsion pendulum for testing enhancements to the LISA Gravitational Reference Sensor

John Conklin[1], Andrew Chilton[1], Giacomo Ciani[1], Guido Mueller[1], Taiwo Olatunde[1], Ryan Shelley[1]
1. University of Florida, Gainesville, FL, United States.

The Laser Interferometer Space Antenna (LISA), the most mature concept for observing gravitational waves from space, consists of three Sun-orbiting spacecraft that form a million km-scale equilateral triangle. Each spacecraft houses two free-floating test masses (TM), which are protected from disturbing forces so that they follow pure geodesics in spacetime. A single test mass together with its housing and associated components is referred to as a gravitational reference sensor (GRS). Laser interferometry is used to measure the minute variations in the distance between these free-falling TMs, caused by gravitational waves. The demanding acceleration noise requirement of 3E–15 m/sec^2Hz^1/2 for the LISA GRS has motivated a rigorous testing campaign in Europe and a dedicated technology mission, LISA Pathfinder, scheduled for launch in 2015. Recently, efforts have begun in the U.S. to design and assemble a new, nearly thermally noise limited torsion pendulum for testing GRS technology enhancements and for understanding the dozens of acceleration noise sources that affect the performance of the GRS. This experimental facility is based on the design of a similar facility at the University of Trento, and will consist of a vacuum enclosed torsion pendulum that suspends mock-ups of the LISA test masses, surrounded by electrode housings. The GRS technology enhancements under development include a novel TM charge control scheme based on ultraviolet LEDs, simplified capacitive readout electronics, and a six degree-of-freedom, all-optical TM sensor. This presentation will describe the design of the torsion pendulum facility, its expected performance, and the potential technology enhancements.

248.15 – Analysis Method for the Drift-Mode Experiment on LISA Pathfinder

Curt Cutler[1], James Thorpe[2]
1. Jet Propulsion Laboratory, Pasadena, CA, United States. 2. Goddard Space Flight Center, Greenbelt, MD, United States.

One of the most important planned experiments on the LISA Pathfinder mission is the Drift-Mode experiment. In this experiment, one of the two test masses repeatedly gets a "kick" from the DC actuation system, then drifts for ~200 seconds, is kicked again, and this repeats. The DC actuation (in the sensitive direction) is turned off while the test mass is drifting. This experiment was designed to permit measurement of the acceleration noise on the test mass when the DC actuation is off, which is the situation that will normally hold on LISA itself. The data analysis will be considerably complicated by the fact that the frequency of kicks is right in the band of interest. Here we demonstrate an analysis algorithm that successfully handles the complications.

249 – NITARP: The NASA/IPAC Training in Archival Research Program

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

249.01 – NITARP: Impact Assessment, 2005-2013

Luisa M. Rebull[1], Varoujan Gorjian[1], Carolyn Brinkworth[1], Gordon K. Squires[1], Kim Burtnyk[2]
1. Caltech, Pasadena, CA, United States. 2. Science for Society, South Pasadena, CA, United States.

NITARP, the NASA/IPAC Training in Archival Research Program, gets educators involved in authentic astronomical research. We partner small groups of educators with a mentor professional astronomer for a year-long original research project. The educators incorporate the experience into their classrooms and share their experience with other teachers. The teams echo the entire research process, from writing a proposal, to doing the research, to writing up and presenting the results at an AAS meeting. The educators incorporate this experience into their classroom. This program differs from other programs that we know of that get real astronomy data into the classroom in that: (a) Each team works on an original, unique project. There are no canned labs here! (b) Each team presents their results in posters at the AAS, in science sessions (not just outreach sessions). The posters are distributed throughout the meeting, in amongst other researchers' work; the participants are not "given a free pass" because they are teachers. (c) The 'product' of this project is the scientific result, not a curriculum packet. (d) Because the teachers work with students throughout this project, the teachers have already begun to adapt their project to fit in their classroom environment. This poster will describe the program, with highlights of an impact assessment survey conducted of NITARP alumni in June 2013. Including all forms of the project from 2004-2013, there have been 80 educator participants from 33 states; 40 of them responded to our survey. There have been 37 science and 42 education AAS posters presented by NITARP-affiliated educators and scientists (with 8 more expected to be presented at this meeting). There have been 5 refereed journal articles in professional astronomy research journals that directly involve NITARP teachers and scientists (Howell et al. 2006, Guieu et al. 2010, Howell et al. 2008, Rebull et al., 2011, 2013), and 2 more astronomy journal articles describing the software developed in conjunction with NITARP and its Spitzer (Laher et al. 2012ab). There is one more refereed article written by a NITARP alumni teacher for The Physics Teacher (Pereira et al. 2013).

249.02 – NITARP Alignment with Common Core Literacy and Mathematics Standards

Nicole Granucci[3], Varoujan Gorjian[1], Theresa Paulsen[4], Thomas Rutherford[2], John Blackwell[5]
1. JPL/California Institute of Technology, Pasadena, CA, United States. 2. Sullivan South High School, Kingsport, TN, United States. 3. Oxford High School, Oxford, CT, United States. 4. Ashland High School, Ashland, WI, United States. 5. Phillips Exeter Academy, Exeter, NH, United States.

NASA/IPAC Teacher Archival Research Program (NITARP) is an authentic research experience that partners teachers and students from around the country to participate in data extraction and analysis with a mentor astronomer from the Spitzer Science Center. The goal of the research is to determine a relationship between luminosity and temperature of Type I Seyfert galaxies between redshifts of 0.1 and 0.8 using data from the Sloan Digital Sky Survey and Galaxy Evolution Explorer archives. Members of this group participated in weekly teleconferences, a trip to Caltech and Google Hangouts to communicate and analyze data. This program meets common core standards in modeling, statistics and probability, and science/technical writing standards in literature. This is evident in data extraction, manipulation of data/variables, analysis of trend lines, and communication, all of which are integral parts of the research conducted with this project. The NITARP program is an optimal teaching tool for meeting national common core standards.

249.03 – Extending the invitation: Supporting learners from gateway experiences to participating in astronomical research

Wendi Laurence[1], John Gibbs[2], Robert Marshall[3], Michael Murphy[4], Laura Orr[5], Luisa M. Rebull[6], Christi Whitworth[7]
1. Portland State University, Porltand , OR, United States. 2. Glencoe High School, Hillsboro, OR, United States. 3. Carnegie Science Center, Pittsburgh, PA, United States. 4. Ravenscroft School, Raleigh, NC, United States. 5. Ukiah High School, Ukian, OR, United States. 6. Caltech, Pasadena, CA, United States. 7. Pisgah Astronomical Research Institute, Asheville, NC, United States.

NITARP provides a forum in which educators conduct authentic astronomical research with guidance from practicing astrophysicists within an interactive professional learning community. As educators learn to conduct astronomical research, they are simultaneously creating educational outreach programs that connect other educators and secondary students to the research process. This means that, at any given time, participants may be learning astronomical content knowledge, field-specific research methodology, computer programs or devising teaching curricula and methods to extend the research experience to others. To support future endeavors, education research methodologies were employed to document the critical junctures where learning might be thwarted (Laurence, Kelley, Becker, Day & Marshall, 2006). These findings benefit the field in general as conducting authentic research is a key initiative in science education. NITARP also fills a unique

critical juncture in the astronomical field. While astronomy is often called a gateway science there remains a precipitous drop-off in the number of students or educators who choose to extend their learning beyond planetarium experiences and introductory courses. To provide an invitation into research, and effective support along the way, we asked the question: What supports and cognitive frameworks learners would need to move from observation to research? Our poster will highlight three necessary skill sets: 1) Visualization constructed from multiple sets of data and images to create data driven conclusions; 2) Team research engagement practices, focused on grappling with data that does not have THE answer but rather a series of patterns or comparisons; 3) The use of multiple software programs, trouble shooting and compatibility. Our poster will discuss the teaching challenges and supports we developed to bring students through the research process and widen the gateway to STEM learning. This project was made possible through the NASA/IPAC Teacher Archive Research Project (NITARP) and was funded by NASA's Astrophysics Data Program and Archive Outreach funds.

249.04 – An Initial Analysis of Learning Styles Exhibited by High School Science Students

Frederick Donelson[1], Holly Bensel[2], Danielle Miller[3], Sally Seebode[4], David R. Ciardi[5], Steve B. Howell[6]
1. Gahanna Lincoln High School, Gahanna, OH, United States. 2. St. Mary's School, Medford, OR, United States. 3. University High School, Orlando, FL, United States. 4. San Mateo High School, San Mateo, CA, United States. 5. NExScI, Pasadena, CA, United States. 6. NASA ARC, Mountain View, CA, United States.

Educational research magazines are filled with information on learning styles and how they affect the learning process, but few studies have been conducted to specifically look at learning styles exhibited by high school science students. This project attempted to obtain a general "snapshot" of learning styles found in the high school science classroom, and then compare that to one derived from a subgroup of highly motivated science students involved in a NITARP student team. Control students (N=54) from elective science courses at four high schools (urban, suburban, and rural) were administered the Felder Learning Style (FLS) assessment and rated on Likert scales in four learning constructs: Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global. NITARP student team members (N=7) were given the FLS before project work began, and then re-tested approximately three months later, after project work concluded. Chi Square Analysis showed no clear significant difference between the general group and the NITARP group (p = .52). Both groups tended to be very visual and sequential, but more reflective than active. The results suggest several concerns that science teachers may need to address: (1) Research shows best practice science classes often are hands on, yet a majority of students are more reflective than active; (2) Big ideas tend to be better understood by global students, but a majority are more sequential; (3) Since a majority of students are visual, information given verbally may not be very effective. Further research is indicated for these areas of discontinuity. This research was conducted as part of the NASA/IPAC Training in Archival Research Project (NITARP) and was funded by NASA Astrophysics Data Program and Archive Outreach funds.

249.05 – Enhancing Scientific Literacy in the Northeast Kingdom

John Blackwell[1,2], Ben Moss[2], Sidney Wanzer[2]
1. Phillips Exeter Academy, Exeter, NH, United States. 2. Northeast Kingdom Astronomy Foundation, Peacham, VT, United States.

An observatory in the Northeast Kingdom of Vermont opens to assist surrounding elementary and high schools with science literacy using astronomy as a capstone science, introducing students to advanced instrumentation, scientific method and data manipulation skills.

249.06 – Charming the Snake: Student Experiences with Python Programming as a Data Analysis Tool

Melissa Booker[1], Carol B. Ivers[3], Margaret (Peggy) Piper[4], Lynn Powers[5], Babar Ali[2]
1. Robinson Secondary, Centreville, VA, United States. 2. Caltech, Pasadena, CA, United States. 3. Foran High School, Milford, CT, United States. 4. Lincoln-Way North High School, Frankfort, IL, United States. 5. Bozeman High School, Bozeman, MT, United States.

During the past year, twelve high school students and one undergraduate student participated in the NASA/IPAC Teacher Archive Research Program (NITARP) alongside three high school educators and one informal educator, gaining experience in using Python as a tool for analyzing the vast amount of photometry data available from the Herschel and Spitzer telescopes in the NGC 281 region. Use of Python appeared to produce two main positive gains: (1) a gain in student ability to successfully write and execute Python programs for the bulk analysis of data, and (2) a change in their perceptions of the utility of computer programming and of the students' abilities to use programming to solve problems. We outline the trials, tribulations, successes, and failures of the teachers and students through this learning exercise and provide some recommendations for incorporating programming in scientific learning.

249.07 – Looking Inside XX Cygni

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1. Freeport Public Schools, Freeport, NY, United States. 2. Caltech, Pasadena, CA, United States.

Light curves of XX Cygni, an SX Phe type variable in the constellation Cygnus, are obtained using visible and blue filters. From the light curves, we obtain temperature, radius, and radial velocity throughout the pulsation period. Assuming the pulsation to be purely radial, the linear adiabatic wave equation can provide a limit on pressure scale height at the surface of the star. Our high school students are exposed to information about this star through the `lens' of a telescope and through the `lens' of an equation.

250 – AGN, QSO, Blazars Poster Session I
Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

250.01 – Analysis of Quasar Variability Using Kepler Quarter 14 and 15 Data

David Nowak[1], Mitchell Revalski[1], Paul J. Wiita[1], Ann E. Wehrle[2], Stephen C. Unwin[3]
1. The College of New Jersey, Ewing, NJ, United States. 2. Space Science Institute, Boulder, CO, United States. 3. Jet Propulsion Lab, Pasadena, CA, United States.

The Kepler space telescope was originally intended to search for exoplanets with its sensitive photometric capabilities; however, it also can be used to observe distant quasars or active galactic nuclei (AGN). We acquired additional Kepler data for four radio-loud AGNs for quarters 14 and 15. Two of our objects are relatively inactive, one was fairly active and the last AGN was heavily contaminated by instrumental effects (moiré) in one of the quarters. We ran the data through a series of programs that corrected for various gaps and glitches that were present along with some other instrumental aberrations. We also endmatched the data so that the beginning and end of the individual quarters had the same average photon counts. The overall result was continuous data for the whole quarter with data points every 30 minutes. We have now mostly automated the pipeline so that only specific cases, such as solar flares, need to be corrected manually. We then computed power spectral densities (PSDs) on both the corrected and uncorrected Kepler data and found that they had similar slopes though our corrections process tended to slightly steepen the slopes of the PSDs for the quarterly data. The slopes of the endmatched data tended to be shallower than the other slopes. In general, for both corrected and uncorrected data, the slopes are comparable to those calculated using ground based observations and lie within the range of -1.6 to -1.9 for our active objects. There were no periodicities or quasi-periodicities found in the data for all objects in the two quarters but this is unsurprising. The similarities of the slopes for the corrected and uncorrected data indicated that our correction process has not changed the data significantly. Our goal was to correct the data so that individual quarters can then be stitched together to form a longer stretch of data. With this combined data are able to probe lower frequencies with our PSDs and consider the long term variability of the AGN. This work was supported in part by NASA Kepler GO Grant NNX11AB90G and MUSE funds through The College of New Jersey.

250.02 – Investigating AGN Variability Using Combined Multi-Quarter Kepler Data

Mitchell Revalski[1], Dawid Nowak[1], Paul J. Wiita[1], Ann E. Wehrle[2], Stephen C. Unwin[3]
1. The College of New Jersey, Glen Gardner, NJ, United States. 2. Space Science Institute, Boulder, CO, United States. 3. Jet Propulsion Laboratory, Pasadena, CA, United States.

The study of long and short term variability in active galactic nuclei (AGN) yields deeper insight into the physical nature of their emissions from the accretion disk around, and relativistic jets powered by, a galaxy's central super-massive black hole. We have now obtained a total of eleven quarters of Kepler data on four radio-loud AGN. Our prior work involved calculating power spectral densities (PSDs) on these data both with and without corrections for various instrumental artifacts. We now focus on combining these data sets into one continuous set for each object which spans approximately 2.5 years at a 30 minute sampling rate with >98% duty cycle. The process of stringing together these data is complicated by the quarterly rolls the Kepler space satellite telescope conducts, which causes each target to fall on a different CCD four times per year. We attempt to overcome this problem with a scaling procedure that maintains the original percentage of variations and scales all eleven quarters to the overall average. We calculate PSDs on these stitched light curves both with and without various end-matching techniques applied to increase the accuracy of the PSDs. The PSDs computed for the stitched light curves allow us to probe a full decade lower in frequency than our previous work and show comparable slopes to the PSDs calculated for individual quarters, suggesting we are linking the quarters appropriately. Our average PSD slopes are consistent with ground based observations of other quasars, falling approximately between -1.6 and -1.9. In addition, we have used original codes to bin and average individual PSDs to reduce the bias introduced on the slope fitting process induced by the uneven population of points in the PSDs. This allows for a more accurate power law fitting and tends to steepen the overall slope by approximately 0.1 in the majority of cases. We note increased flaring in one of our objects on the order of 15%, with our remaining three objects being more quiescent with occasional flaring. This work was supported in part by NASA Kepler GO Grant NNX11AB90G and MUSE funds through The College of New Jersey.

250.03 – Analysis of Kepler Lightcurves Using Turbulent Jet Model

Sarah M. Dhalla[1], James R. Webb[1], Gopal Bhatta[2], Douglas Laurence[1]
1. Florida International University, Miami, FL, United States. 2. Jagiellonian University, Krakow, Poland.

From 2010-2013, Kepler monitored the optical emission from four active galactic nuclei (AGNs) with high resolution. We use the turbulent jet model to analyze the micro-variations seen in these Kepler AGN. The turbulent jet model assumes that when a shock wave passes though the turbulent jet of a Blazar, each turbulent cell encountered produces a pulse of emission whose size and shape depend on cell size, the local density enhancement, and the magnetic field strength. From this analysis we infer some of the important parameters of the turbulent flow of the jet.

250.04 – Photometric Monitoring of the Active Galactic Nucleus in NGC 7469

Caroline A. Roberts[1], Misty C. Bentz[2]
1. Sewanee: The University of the South, Sewanee, TN, United States. 2. Georgia State University, Atlanta, GA, United States.
Contributing teams: Stare Collaboration

Reverberation mapping is a technique by which black hole masses in active galactic nuclei (AGN) are determined. The method determines an average radius for the broad line region by measuring the time delay between continuum and emission signatures in an object's spectrum. Coupled with the broad line region cloud velocity values taken from Doppler emission line broadening and a correction for the angle at which the AGN is viewed, the black hole mass can be constrained. As part of a reverberation mapping campaign targeting NGC 7469, optical B and V photometry was obtained over the span of a 6-month period during the second half of 2011 using 14 different telescopes in the former bandwidth and 15 in the latter. Differential photometry was performed with IRAF and the light curves were compared with those obtained using the image subtraction program ISIS.

250.05 – Using Swift to Search for Fast X-ray Variability from Blazars and Study Jet Emission

Matthew Pryal[1], Abraham Falcone[1], Michael Stroh[1]
1. The Pennsylvania State University, University Park, PA, United States.

Since its launch, the Swift X-ray Telescope has obtained 0.2-10 keV X-ray data on numerous blazars over a variety of time periods, ranging from seconds to more than 8 years.Much of these data come from intense target of opportunity observations that can be analyzed in a multiwavelength context and used to model jet parameters, particularly during flare states, and another large component of these data come from monitoring data that was obtained during a variety of flux states. By looking at this broad data set, one can evaluate variability timescales and limit the emission mechanisms and associated parameters.In particular, we will report on our search for short timescale variability that could limit the size of the emission region in the blazar jet.

250.06 – Detecting a Jet and Tidal Tail in HST Images of Pictor A

Eric S. Gentry[1], Herman L. Marshall[1], Eric S. Perlman[3], Mark Birkinshaw[4], Martin Hardcastle[2], D. E. Harris[6], Emil Lenc[5], Aneta Siemiginowska[6], C. M. Urry[7], Diana M. Worrall[4]
1. Massachusetts Institute of Technology, Cambridge, MA, United States. 2. University of Hertfordshire, Hatfield, United Kingdom. 3. Florida Institute of Technology, Melbourne, FL, United States. 4. University of Bristol, Bristol, United Kingdom. 5. CSIRO Australia Telescope National Facility, Epping, NSW, Australia. 6. Smithsonian Institution Astrophysical Observatory, Cambridge, MA, United States. 7. Yale University, New Haven, CT, United States.

New images from the Hubble Space Telescope (HST) of the radio galaxy Pictor A reveal a 60kpc tidal tail and 5" long jet knot. This observation was prompted by X-ray observations with the Chandra X-ray Observatory, which revealed a highly collimated jet over 1.9' long (Wilson et al. 2001) that was only recently clearly detected at 4.8 GHz with the Australian Telescope Compact Array (Marshall et al. 2010). HST observations were taken using the WFC3 at 1600nm, 814nm, and 475nm. After subtracting a model of the host galaxy, a giant elliptical, we measured the core flux, the tidal tail and the jet feature. The formation of the tidal tail provides possible insight to what triggered AGN activity within Pictor A. The jet knot at 30" from the core is clearly extended about 5" along the jet at 1600nm but is faint and point-like at 814nm and not detected at 475nm. The fluxes from the HST images are compared to models of synchrotron and self-Compton emission, and further refine conclusions drawn from jet and knot features in x-ray and radio images. Finally, we measure the fluxes of the active nucleus in Pictor A in three optical bands to compare to previous X-ray and radio measurements. Support for this work was provided in part by NASA through grant GO-12261.01-A from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555

250.07 – Investigating C IV Line Variability and Multiple Epoch C IV SMBH Mass Estimates

Ramon Sharma[1]
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The CIV emission line in quasar spectra is well-known to show systematic blueshifts, often attributed to accretion disk winds. We investigate the variability of the CIV line properties in a large sample of multi-epoch quasar spectra from the SDSS BOSS survey DR10, focusing on correlations of the blueshift variability with line and continuum properties. Preliminary findings show very weak to no variability in the blueshifting of the region of interest and weak correlation between line blue-shift and

change in continuum flux between epochs, indicating near constant outflow speeds. We will also continue to investigate the use of multiple epoch luminosities of the CIV line as a probe of virial mass of the host SMBH. By recalibrating estimates built on the use of single epoch data and correcting for any changes in outflow speed, it is hoped to more finely tune BH mass estimates.

250.08 – Monitoring the Lensed Quasars FBQ 0951+2635 and SDSS 1650+4251 in the Near-Infrared: Technical Challenges

Aaron Demers[1], Gregory Gerlach[1], Christopher W. Morgan[1], Chelsea MacLeod[1], Frederick J. Vrba[2]
1. US Naval Academy, Annapolis, MD, United States. 2. us Naval Observatory, flagstaff, AZ, United States.

We present two seasons of J- and H-band imagery of the doubly-lensed quasars FBQ 0951+2635 and SDSS 1650+4251 taken using the ASTROCAM infrared imager on the 1.55m Kaj Strand Reflector at the US Naval Observatory (USNO), Flagstaff AZ. The data were taken as a component of the US Naval Academy (USNA)-USNO lensed quasar monitoring program, whose primary objective is the use of quasar microlensing to constrain the physical properties of the quasar continuum source. In this investigation, the brightness of the blended multiple images are deconvolved from the flux from the lens galaxy using a variety of techniques including point-spread function modeling and difference imaging in an effort to pick to most reliable technique for our data reduction pipeline.

250.09 – II ZW 229.015: The most complete optical light curve of any AGN.

Joshua Williams[1], Michael T. Carini[1]
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II ZW 229.015 is the brightest AGN in the Kepler field of view. It has been extensively monitored with both the Kepler spacecraft and ground based observatories since the beginning of the Kepler mission. The Kepler light curve is unmatched by any optical light curve ever obtained for an AGN. In this poster we present the Kepler and ground based light curve spanning the entire Kepler mission. Using the Kepler light curve, we have performed a time series analysis using the PSRESP methodology and determined a characteristic variability time scale and mass of the central supermassive black hole in II ZW 229.015. We compare this result to the previous mass estimates from variability and reverberation mapping studies of II ZW 229.015.

250.10 – Outburst in the Gamma-ray Bright Quasar CTA26

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We analyze multi-waveband space- and ground-based observations of the z=0.852 quasar CTA26 (PKS 0336-019) over a 6-year time span that includes two gamma-ray outbursts. The instruments used include the Fermi Gamma-ray Space Telescope, the Very Long Baseline Array (VLBA), the Perkins Telescope at Lowell Observatory, and a number of other optical telescopes. We cross-correlate the time variations from the different wavebands and compare the timing of the gamma-ray events with changes in the jet seen in VLBA images at 43 GHz, with a resolution of 100 micro-arcseconds, to determine the relationship between the conditions in the jet and the high-energy outbursts. A total of 39 VLBA images were collected from June 2007 to February 2013 at near bimonthly intervals. We analyze the multi-frequency behavior of the quasar during two prominent gamma-ray outbursts, in late 2010 and late 2011. An increase in the flux in the VLBA images during mid to late 2010 marked the appearance of a new superluminal knot that proceeded to emerge from the mm-wave core as a gamma-ray flare erupted. A similar sequence of events occurred almost a year before the outburst in late 2011, although the associated superluminal knot was not as fast. Our analysis shows radio, optical, and gamma-ray fluxes peaking contemporaneously during these two events, with the maximum of the optical/gamma-ray correlation agreeing within a few days, and with the radio peak occurring about 1 month earlier. Each outburst ended after 3 months at gamma-ray energies, while the radio emission decayed more slowly, with a plateau between the two outbursts. We infer the degree of order and geometry of the magnetic field during the outbursts by studying the linear polarization at both radio (in the images) and optical wavelengths. We use the changing positions of the superluminal knots to locate the gamma-ray flares in the parsec-scale jet. Armed with this information, we compare the evolution of the jet of CTA26 with the expectations of current models, such as those that include moving and/or standing shocks in the parsec-scale jet. This research was supported in part by NASA through Fermi Guest Investigator grant NNX11AQ03G.

250.11 – Quasar Ionization Echoes -- 100,000 Year Baseline AGN Light Curves

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Green Bean galaxies (GBs, Schirmer et al. 2013) are extremely rare type-2 AGN. Only 17 were found in the 14,500 square degrees SDSS-DR9, with redshifts in the range 0.19 < z < 0.34. They feature ultra-luminous and large (up to 100 kpc) narrow-line regions (NLRs) with typical [OIII] luminosities of several 1e43 erg/s. Comparing [OIII] and 22micron WISE luminosities with those of other type-2 quasars, we found the GB [OIII] luminosities to be 5-50 times higher than expected from the control sample. This implies that the central supermassive black hole (SMBH) engines in GBs currently undergo a substantial decline, while the NLR is still being ionized by the escaping X-ray radiation. These ionization echoes provide a unique window into what could be the final shut-down process of quasars. In our project we combine high-resolution narrow-band imaging with ACS/HST, IFU spectroscopy with GMOS/Gemini, and X-ray data with Chandra to study the ionization echoes further. Using the spatially resolved NLRs and the finite speed of light, we can reconstruct individual AGN X-ray light curves over a baseline of up to 100,000 years. This is the same time-scale as predicted for the shut-down by accretion models, and has not been probed previously. Combining the AGN's long-term variability with the physical properties of the luminous NLR then allows us to study the formation of the latter, together with AGN feedback and the impact on star formation in these exotic galaxies.

250.12 – Time-Correlation Between Optical and Gamma-ray Activity in Blazars

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We have been using the 0.76-m Katzman Automatic Imaging Telescope (KAIT) at Lick Observatory to monitor a sample of 156 blazars that are bright in gamma-rays, being detected with high significance (test-statistic > 100) in one year by the Large Area Telescope (LAT) on the Fermi Gamma-ray Space Telescope. We attempt to observe each source on a 3-day cadence, subject to weather and seasonal visibility. The gamma-ray coverage is essentially continuous. KAIT coverage extends over much of the 5-year Fermi emission for a few objects, and for the bulk of the sample we have at least 100 optical measurements covering 2+ years. These blazars (flat spectrum radio quasars and BL Lacs) exhibit a wide range of flaring behavior. We search for temporal relationships between optical and gamma-ray light curves using the discrete correlation function (DCF) described by Edelson & Krolik (1988), with a local normalization described by Welsh (1999). We report here on 32 sources showing apparent strong correlation. Several sources show common light-curve features, but the significance of the DCF peaks requires further study. To date no clear lead/lag pattern emerges, although we can hope that such delays, or lack thereof, will allow us to place constraints on the blazar acceleration and emission zones.

250.13 – TANAMI Discovery of a Milliarcsecond-scale Symmetric Radio Structure in the Gamma-ray Source PMN J1603-4904

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Contributing teams: TANAMI Collaboration, Fermi-LAT Collaboration

Recent VLBI observations of the source PMN J1603-4904 at 8.4 and 22.3 GHz by the TANAMI program have revealed a symmetric brightness distribution on milliarcsecond scales. The distribution consists of three resolved components, with the brightest, most compact component located at the center of the distribution. The morphology resembles that of a Compact Symmetric Object (CSO), believed to be the class of young radio galaxies. We present these data, along with a new five-year analysis of PMN J1603-4904 using the Fermi LAT data, in order to examine the possible origin of the gamma-ray emission and to better constrain the source physics through multiwavelength spectral analysis and variability studies.

250.14 – SMARTS Optical and Near-Infrared Observations of Fermi LAT Blazars

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Contributing teams: Fermi Gamma-ray Space Telescope

Since 2008, we have been monitoring southern-hemisphere blazars at optical and near-infrared (OIR) wavelengths using the SMARTS 1.3m+ANDICAM instrument. Our targets are observed simultaneously with the Fermi Gamma-ray telescope providing us with an opportunity to probe the relative contribution of the thermal and non-thermal emission to the broad-band spectral energy distribution. In this poster we present our results which include OIR light curves that, in some cases, show 'orphan' flares in OIR fluxes that are not present in gamma-rays. In addition we see evidence for intra-night variability in some blazars. Discrete correlation functions of simultaneous gamma-ray and OIR fluxes suggest there is no lag

or lead time between OIR and gamma-ray fluxes during some flares. Finally, color-magnitude diagrams of some blazars show clear changes in color over flares allowing us to study the evolution of accretion disk vs. jet emission during flaring events.

250.15 – Spectroscopic Monitoring of Supermassive Black Hole Binary Candidates

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Supermassive Black Hole Binaries (SBHBs) are an inevitable result of the process of hierarchical galaxy mergers during the cosmological buildup of structure. Theories of galaxy evolution seek to explain the observed correlations of black holes and their host galaxies as they undergo successive epochs of mergers and accretion. There are some strong candidates for wide separation SBHBs, but no robust evidence for the expected large population of close SBHBs, at separations of ~1 pc or less. We have undertaken a search for close SBHBs with a sample of 88 candidates, selected from a large sample of AGNs, having broad Hβ emission lines with substantial (1,000 km/s) offsets from the systemic redshift. Multiple epochs of spectroscopic observations can measure any shift in the line offset and, assuming the shift is due to orbital motion within the SBHBs, constrain the curvature of the inferred radial velocity shift and hence place a lower limit on the total mass of the SBHB. Here we present preliminary results of a spectroscopic monitoring campaign of the candidates with the Hobby-Eberly Telescope through April 2012.

250.16 – Time Variation of the Broad Hβ Emission Line in Local Active Galaxies

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High-quality Keck/LRIS long-slit spectra for a sample of 97 Type 1 local active galaxies selected from the Sloan Digital Sky Survey (0.02 ? z ? 0.1; M_{BH} ?10^7 M™) are used to study the relations between black hole mass (M_{BH}) and host-galaxy properties. Of these objects, eight were found to be lacking broad Hβ emission lines previously observed in SDSS spectra. Based on seeing and PSF profile, we can exclude the lack of broad lines in the Keck spectra as being due to a telescope pointing error, missing the central AGN. These AGNs are classified as type 1 or type 1.5 Seyferts according to the characteristic presence of broad lines in SDSS spectra, and as 1.8 or 1.9 Seyferts in Keck spectra. We discuss various explanations for this transition including time variation of the torus, time variation of the broad line region, and galaxy mergers resulting in an AGN off-center from the host-galaxy nucleus (including the possibility of a gravitational recoil). Follow up observations at Lick Observatory are used to constrain the different scenarios.

250.17 – Exploring the Variability of the Fermi LAT Blazar Population

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The flux variability of the approximately 2000 point sources cataloged by the Fermi Gamma-Ray Space Telescope provide important clues to population characteristics. This is particularly true of the more than 1100 source that are likely AGN. By characterizing the intrinsic flux variability and distinguishing this variability from flaring behavior, we can better address questions of flare amplitudes, durations, recurrence times, and temporal profiles. A better understanding of the responsible physical environments, such as the scale and location of jet structures responsible for the high-energy emission, may emerge from such studies. Assessing these characteristics as a function of blazar sub-class is a further goal in order to address questions about the fundamentals of blazar AGN physics. Here we report on progress made in categorizing blazar flare behavior, and correlate these behaviors with blazar sub-type and other source parameters.

250.18 – Variability in the Intrinsic Absorption in the Seyfert 1 Galaxy NGC 3783

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We present new results on the variability of the intrinsic absorption in Seyfert 1 galaxy NGC 3783 based on spectra obtained with the Cosmic Origins Spectrograph aboard the Hubble Space Telescope in 2011 and the Far Ultraviolet Spectroscopic Explorer in 2004. The highest velocity absorber continued its decrease in radial velocity initially observed in an intensive

monitoring campaign a decade ago, decreasing from -1320 km/s in 2001 to -1110 km/s in 2004. However, the rate of change in radial velocity decreased over this interval compared to the monitoring campaign and changed very little between 2004 and 2011. These results provide new, tighter constraints on the geometry of the outflow system giving rise to this absorption. We explore the implications of these results for the different dynamical models of AGN outflows.

250.19 – A systematic search for X-ray cavities in galaxy clusters, groups, and elliptical galaxies

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AGN feedback is considered one of the most important phenomena for solving the "cooling flow" problem and driving the galaxy-SMBH co-evolution. As some of the strongest evidence for AGN feedback, X-ray cavities are useful for investigating AGN feedback over 10 kpc scales. Furthermore, X-ray cavities are believed to be connected with radio outbursts from AGN. By collecting all available X-ray data from the Chandra archive, we build up a sample of ~200 targets, including galaxy clusters, galaxy groups, and elliptical galaxies, in order to conduct a comprehensive study of X-ray cavities in various environments. Using modeling and unsharp masking techniques, we investigate the presence of X-ray cavities and their physical properties (i.e., cavity size) for the ~120 targets with enough X-ray photons to perform the analysis. Here, we present our first results on the X-ray cavity properties and discuss environmental effects.

250.20 – Feedback in the Local Universe: The Relation Between Star Formation and AGN Activity in Typical Elliptical Galaxies

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Aim: We address the relation between star formation and AGN activity in a large sample of nearby early type (E and S0) galaxies. Feedback from the AGN is believed to play an important role in regulating star formation. Earlier studies of AGN feedback have focused on large systems, i.e. cooling flow clusters and/or X-ray selected sources and none of the studies looked at the relation between star formation and AGN activity in typical elliptical galaxies. Methods: We carried out a multi-wavelength study of a sample of 236 elliptical galaxies which were chosen to have an apparent K magnitude brighter than 13.5 and whose positions correlate with Chandra ACIS-I and ACIS-S sources. The galaxies in the sample are unbiased regarding their star formation and radio source properties. Using the archival observations at radio, ultraviolet and infrared from VLA, GALEX and WISE respectively, we obtained the radio power and total flux values to study AGN activity and star formation. Results: There is an upper envelope of radio power that is a steep function of absolute K-band magnitude of the galaxy suggesting that the maximum possible jet power is dependent on the brightness of the galaxy and thus on the mass of the galaxy. A color-color diagram between [FUV-K] vs [FUV-NUV] shows the presence of bluer galaxies indicating the presence of star formation in the sample. Radio power and [FUV-K] color is uncorrelated suggesting that perhaps fueling of radio sources is not associated with substantial star formation or perhaps the radio jets have suppressed star formation. All the star forming galaxies identified in the sample are less massive and radio faint. Hot dust is observed in only a small subset of the objects, suggesting that in most of the galaxies, AGNs are accreting in a process that is radiatively inefficient. In a subset of galaxies, much of the star formation is obscured by dust.

250.21 – Large Radio Sources Hosted by Spiral Galaxies (aka: The Wrong Type of Host!)

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In the local Universe, double-lobed, powerful radio sources are almost always hosted by elliptical galaxies, and those hosted by spiral galaxies are extremely rare. To date, only one, 0313-192, has been confirmed (Ledlow et al. 2001; Keel et al. 2006). 0313-192's host galaxy is an edge-on spiral confirmed to be the source of the double-lobed radio emissions. A number of possible factors have been proposed to explain this occurrence, including extrinsic environmental factors, an unusually luminous bulge in the spiral galaxy, and prior minor merger activity. Other candidate spiral galaxies hosting double-lobed radio sources have been identified, but none as convincingly as 0313-192. Many of these candidates have been shown to be misclassified ellipticals or chance alignments, including the famous example of PKS 0400-181 (Shaver et al. 1983). In an attempt to further our understanding of spiral galaxies that host double-lobed radio sources, we began a project to search for more of these enigmatic sources and estimate a number density to describe their occurrence. During the course of this

research, a second spiral galaxy that appears to be hosting a double-lobed radio source was identified, J164924.01+263502.6.

250.22 – Morphological Classifications of the Nuclear Disks and Radio Jets for a Complete Sample of Nearby Radio-Loud Elliptical Galaxies

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Contributing teams: The UGC FR-I Collaboration

We present two new classification schemes for a complete sample of 21 nearby radio galaxies based on the morphology of the nuclear gas/disk and the morphology of the radio jets. We present independent three-level morphological classification keys based on the parameters of the nuclear gas/dust disks, and the extended radio jets respectively. A comparison between the two classifications shows strong correlations between nuclear disk morphology classifications and radio jet morphology classifications, suggesting that there are correlations between the larger scale nuclear gas and dust and the central engine.

250.23 – From Starburst to Quiescence: Testing AGN Feedback in Post-Starbursts Galaxies.

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Using SDSS, GALEX, and WISE observations, we trace the evolutionary sequence from starbursts to quenched post-starbursts and identify intermediate post-staburts population with active star-formation or/and AGN. We find that AGN are twice more common in these transiting post-starbursts than they are in normal galaxies. However, the AGN in these objects appear significantly delayed, atleast by couple of hunderd million years, from the starbursts phase, as also shown by previous works. Therefore, we conclude that AGN do not play a primary role in quenching starbursts but may be responsible for quenching low-level star-formation in post-starbursts galaxies.

250.24 – Relative Influence of Galaxy Mergers and Clusters on AGN Activity

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We investigate the connection between the accretion of central black holes and the intergalactic environment with a newly developed technique. Using 551,924 galaxies from the Sloan Digital Sky Survey (SDSS), supplemented by improved data on galaxy mergers and clusters, we study how AGN activity varies across environments. We apply a continuous measure of AGN activity to all galaxies and then determine how it changes between samples specifically matched to isolate environmental effects while removing contamination. We find consistent merger-induced enhancement and cluster-induced suppression of AGN activity, with the influence of clustering dominant over merging. These results can be explained through models of gas dynamics in which mergers increase gas delivery and clusters reduce gas availability.

250.25 – Active Galactic Nuclei in Dwarf Galaxies

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Supermassive black holes (SMBHs) one million to a few billion times the mass of our sun are thought to reside in the center of most, if not all, bulge-dominated galaxies. It has been observed that the mass of these SMBHs is strongly correlated with the mass of these bulges, leading to the popular view that these central black holes are formed by galaxy mergers, which induce the growth of the galaxy's bulge and provide matter with which to feed the black hole. Although these properties and their possible consequences have been studied extensively in high mass galaxies and galaxies with large bulges, there is very little research on the possible existence and subsequent properties of SMBHs in low mass galaxies or galaxies with small or no central bulges. This is a significant weakness in the research of these objects as the study of this population of galaxies would allow us to gain valuable insight into SMBH seeds, black holes thought to have formed in the early universe. Strong X-rays are a good indicator of an accreting black hole, because they require more energy to produce and SMBHs are highly energetic, as well as being easier to see due to their ability to penetrate matter more easily than other forms of radiation. In this poster, I will present the results from an X-ray investigation using data matched from the Chandra X-ray observatory to a sample of low mass galaxies (with a mass of $\log(M) < 9$).

250.26 – Obscured Active Galactic Nuclei in Dwarf Galaxies

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Whereas supermassive black holes (SMBHs) are found in a vast majority of galactic bulges, very few SMBHs have been confirmed in low mass dwarf galaxies. Identifying such a population could provide clues to the origins of SMBHs and an understanding of the secular pathways for their growth. Using the Point Source Catalogs from the XMM-Newton and Chandra archives, we report the discovery of a population of low mass dwarf galaxies (log M/Msolar<9) with hard X-ray point sources, indicative of an active galactic nucleus. In contrast to optically identified AGNs in the low mass regime, this population lacks evidence of accretion activity in the optical. We discuss the properties of these galaxies and the significance of their discovery.

250.27 – Color-Magnitude Relationship of Type I Seyfert Galaxies with Redshifts from 0.1<z<0.8 Using Data From Sloan and GALEX

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Data from the Sloan Digital Sky Survey (SDSS) and the Galaxy Evolution Explorer (GALEX) satellite were used to construct color-magnitude diagrams of Type I Seyfert galaxies with redshift values of 0.1<z<0.8 This study improved upon previous studies by having a much larger sample size (almost 1900 objects) and by increasing the covered wavelengths from 0.15 microns to 0.9 microns. Color was plotted against absolute magnitude in several bandwidths, from the far UV to the near infrared. Significant correlations were found at certain z-values.

250.28 – Red Quasars: Hunting For Hidden Rubies in the Sky

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Energetic galactic nuclei, known as quasars, have typically been thought of as blue objects. Over the past decade, however, the existence of a population of red quasars has emerged, revealing a new frontier in the study of these objects. Techniques for efficiently finding red quasars are needed, and we are exploring various selection methods for identifying them in large photometric surveys. Combining IR and optical photometry from UKIDSS and SDSS, we have found a way to separate red quasar candidates from most other sources more effectively than using optical data alone. After our technique proved successful with known red quasars, we applied it to a sample of random objects chosen from a small patch of sky. Investigating those objects that qualified as likely candidates, we found that a large fraction, approaching 50%, were red quasars. This selection technique was then used to make a list of red quasar candidates for further investigation with SpeX at IRTF. Our method for effectively identifying red quasars, using only photometric data, will improve statistics of the red population of quasars. In our small sample area alone, we were able to find over a 1,000 red quasar candidates, implying their numbers may be a significant fraction of all quasars in the universe, perhaps even the majority. Developing a reliable method to find these objects will increase our understanding of the relation between red and blue quasars and the quasar phenomenon in general.

250.29 – Extending the Fermi – Swift Joint AGN Sample

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The Swift BAT and the Fermi LAT each provide excellent sky coverage and have led to impressive compilations of extragalactic source catalogs. For the most part they sample separate AGN subpopulations – Swift the lower-luminosity and relatively nearby Seyfert galaxies while the Fermi sample is dominated by blazars and does not include any radio-quiet objects. The overlap between these samples is among the radio-loud subset of the Swift sample as has been discussed elsewhere in the literature. The observable properties at these two bands – flux and spectral indices - are not expected to be well correlated as they sample different portions of the synchrotron self-Compton (SSC) spectral energy distribution. In this

contribution we consider an extension of the high-latitude Swift sample by relaxing the significance cut to less than 5 standard deviations and consider the overlap of that subsample with the Fermi AGN catalog. While such a threshold is generally inadvisable as it introduces the strong possibility of spurious detections, the objects of the overlapping sample which are detected at high significance in Fermi can be considered as reasonably high-confidence Swift detections. For example, there are 190 Swift sub-5-sigma Swift sources that have significance >2-sigma with Fermi counterparts, whereas we predict only ~5 due to statistical fluctuation. We also investigate any coincident INTEGRAL/IBIS observations to further bolster or diminish candidate Swift detections. We present our correlation analyses and offer interpretation in the context of the blazar sequence.

250.30 – UV Emission of AGN in the 2Jy Sample of Southern Radio Galaxies

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We present results from a multiwavelength study of 13 objects detected by GALEX. These objects are members of the 2Jy sample of 88 southern radio galaxies. Of these 13 targets, five are quasars, six are radio galaxies and the remaining two are Seyferts. Multiwavelength data are taken from 2MASS, GALEX, and the VLA.

250.31 – A Far-UV to Mid-IR Survey of Nearby Interacting Galaxies and Mergers

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In simulations, encounters between galaxies are predicted to drive gas to the centers of interacting and merging systems triggering new star formation (SF) and active galactic nuclei (AGN). Depending on the rate of SF, large amounts of obscuring dust can make detection of merger-induced activity difficult. To provide better constraints on the importance of obscured and unobscured star production as well as supermassive black hole growth, we use new data from the Wide-field Infrared Survey Explorer (WISE) and the Galaxy Evolution Explorer (GALEX) for a comprehensive sample of 276 major galaxy interactions and 52 mergers with Mstar>10^10 Msun and 0.01<z<0.05 selected from the SDSS. We examine the [3.4]-[4.6] versus [4.6]-[12] micron (W1-W2 vs. W2-W3) color-color plane and find that most interacting galaxies and mergers define a narrow W1-W2 locus that spans a wide range in W2-W3 colors from quiescent to star-forming. We find that a small fraction (2-4%) of our sample have unusually red W1-W2 colors which are associated with obscured (type-2) AGN. Of these, only one-third are Seyferts according to optical emission line ratios, more than one-third are new WISE AGN detections (no SDSS spectra), and the remainder are optical LINERs and SF-AGN composites; none are pure star-formers nor spectroscopically quiescent. We note that new mergers are 3-10 times more likely to host a buried AGN than a galaxy undergoing a tidal encounter. Our preliminary results suggest that intense SF occurs only in a small subset of major, high-mass interactions at late cosmic times. By comparing IR, optical and UV derived SFRs as a function of merger properties, stage, and environment, we hope to better understand the conditions for triggering strong star production and AGN phases.

250.32 – Investigating black hole - galaxy connection from present to past

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The scaling relations between black hole mass and galaxy global properties indicate a close connection between black hole growth and galaxy evolution. Based on the M-sigma relation of the most updated reverberation-mapped AGNs, we determine the virial factor for AGN black hole mass recipes, and applied it to a sample of 42 moderate-luminosity AGNs at z~0.4 and 0.6. The sample has been observed with the HST (ACS, NICMOS, and WFC3) and the Keck telescope in order to measure bulge luminosity and stellar velocity dispersion of their host galaxies. By investigating cosmic evolution of the M-bulge luminosity and M-sigma relations over the last 6 Gyr, we find that black holes in the past lived in a smaller or lower luminosity bulges compared to the present-day black holes, as consistent with various previous works. The uncertainty of the single-epoch black hole mass is still a dominant hindrance in unveiling the nature of the black hole-galaxy connection, particularly at high redshift.

250.33 – GeMS/GSAOI imaging of z ~ 0.3 BL Lacs

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Bright quasars at low z have generally been found in massive, evolved host galaxies, consistent with formation at early epochs. However, deep, high resolution, multicolor imaging of some quasar hosts have found morphological evidence of tidal tails and colors indicative of active star formation. These results are consistent with theories of galaxy formation and evolution in which merger processes trigger the activation of the quasar phase, and energetic feedback is essential. Understanding the role the black hole population plays in the galaxy formation process is important, but imaging the host galaxies around bright quasars is difficult because of the contribution of the bright nuclei. Very high resolution, deep imaging is necessary to successfully remove the nuclear component. We have made high-resolution near-infrared images of several bright z ~ 0.3 BL Lacs with the Gemini Multi-Conjugate Adaptive Optics System (GeMS)/GSAOI in order to study their host galaxies. These targets have optical HST imaging available in the archive, which will allow detailed study of the optical-near-infrared morphology at excellent resolution. This will provide an excellent test of the potential of the large (1 arcmin) AO-corrected field provided by GeMS/GSAOI to study samples of quasar hosts and their nearby environments from the ground.

250.34 – Black Hole Growth in Low-redshift LoBAL QSOs

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We investigate the black hole growth of a volume-limited sample of 22 SDSS-selected Low-ionization Broad Absorption Line QSOs (LoBALs) at 0.5 < z < 0.6 in order to establish the place of those systems in relation to normal quasars and the role that mergers play on those systems. We estimate black hole masses from optical spectra using the width of the broad H beta component and the 5100 angstrom continuum luminosity. We obtain the QSO bolometric luminosities by integrating the optical through far-infrared spectral energy distributions, constructed from archival SDSS, Spitzer IRS, and MIPS observations. Based on a previous morphological study using HST WFC3 observations, this sample is subdivided into mergers and non-mergers. We find that the central black holes of the merger systems have lower masses than those of the non-mergers. The LoBALs span less than an order of magnitude in bolometric luminosity and show no difference between mergers and non-mergers. All LoBALs show sub-Eddington accretion, with similar or lower ratios found in other samples of lower redshifts QSOs. Numerical simulations of gas-rich, merging galaxies predict a short-lived blowout phase characterized by extreme velocity outflows, such as those observed in LoBAL and other BAL QSOs, occurring after the coalescence of the two merging nuclei, immediately following the peak of black hole growth. The range of accretion rates and morphologies found in our sample does not appear to support a scenario where the LoBAL outflows are the result of a collision observed in a specific post-merger stage.

251 – AGN, QSO, Blazars Poster Session II

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

251.01 – The Parsec-scale Structure and Kinematics of Radio-Loud Narrow-Line Seyfert 1 Galaxies

Joseph L. Richards[1], Matthew L. Lister[1], Luigi Foschini[2], Tuomas Savolainen[3], Daniel C. Homan[4], Matthias Kadler[5], Talvikki Hovatta[6], Anthony C. Readhead[6], Tigran Arshakian[7], Vahram Chavushyan[8]
1. Purdue University, West Lafayette, IN, United States. 2. INAF, Brera, Italy. 3. MPIfR, Bonn, Germany. 4. Denison University, Granville, OH, United States. 5. University of Würzburg, Würzburg, Germany. 6. Caltech, Pasadena, CA, United States. 7. University of Cologne, Cologne, Germany. 8. INAOE, Puebla, Mexico.

Narrow-line Seyfert 1 galaxies (NLS1) are a class of active galactic nuclei that share many observational properties with the much more powerful blazar classes. Despite their low black hole masses (typically 10^6-10^8 solar masses) and near- or super-Eddington accretion rates, a small minority are radio loud (RLNLS1s). A growing number of these have been detected in GeV gamma rays by the Fermi Large Area Telescope (LAT), indicating that a relativistic jet has formed in at least some of these sources. This presents a challenge to jet models, but may provide a link between jets found at the small scales of galactic binaries and the large scales of giant quasars. We are carrying out a multifrequency polarimetric radio monitoring campaign of a sample of 15 RLNLS1s using the Very Long Baseline Array (VLBA). Using data from this program, we will expand the currently limited knowledge of the parsec-scale properties and kinematics of this class of sources. We are complementing this campaign with fast-cadence single dish radio monitoring with the Owens Valley Radio Observatory 40m telescope and an optical spectroscopic monitoring campaign using the GHAO 2m-class telescope in Cananea, Mexico.

251.02 – Deconvolving Contributions to the Narrow Emission-Line Spectra of Narrow-Line Seyfert 1s

Steven B. Kraemer[1], D. M. Crenshaw[2], Henrique R. Schmitt[3], Matthias Dietrich[4]
1. Catholic University of America, Washington, DC, United States. 2. Georgia State University, Atlanta, GA, United States. 3. NRL, Washington, DC, United States. 4. University of Ohio, Athens, OH, United States.

We present a continuation of our study of ground-based spectra of a sample of 12 Narrow-Line Seyfert 1s (NLSy1s), obtained using the 1.5m telescope at CTIO. Previously, we had found similar emission line ratios in both NLSy1s and Broad-Line Seyfert 1s (BLSy1s), which suggests similar ionizing continua, although we noted that low-ionization lines, such as [O I] 6300A and such as [S II] 6716,6731A may be somewhat weaker in NLSy1s. Based on photo-ionization modeling, the spectra from both types must include a strong contribution from dense, highly ionized gas in the inner narrow-line region (NLR), as has been noted in the literature. Notably, we find that the average [O III] 5007A/[OII] 3727A ratio is ~ 3.5 in NLSy1s, as compared to ~ 6.5 in a similar-sized sample of BLSy1s, consistent with a strong contribution from star-formation in the former. It is unclear whether star-formation is more prevalent in NLSy1s, suggesting a unique stage in the evolution of the AGN, or whether they tend to lack an extended NLR, which overwhelms any contribution from star-formationand may be due to the orientation of the AGN with the host galaxy.

251.03 – Size of the Narrow Line Region in Low Luminosity AGNS

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1. California State University Los Angeles, Los Angeles, CA, United States. 2. Dartmouth College, Hanover, NH, United States.

We present a study of long slit spectroscopy from the MDM 2.4m Hiltner Telescope to examine the size of the narrow line region (NLR) for a sample of 13 local low-luminosity Type II active galaxies at 0.02 < z < 0.03.We measure the extent of the [OIII] emission line to a limiting surface brightness, to determine the extent to which the central active nucleus can affect large scale gas. We perform these measurements for Seyfert galaxies with 0.02 < z < 0.03, luminosities between 41-45 log(L8µm/ergs s-1) and NLR sizes of 2.9-3.4pc. Early results are consistent with a previously measured slope in the relationship between the NLR size and [OIII] luminosity, consistent with a picture in which the size of the NLR is limited by the availability of gas to be ionized. Future research will involve calculating kinematics of the ionized gas.

251.04 – Reverberation Mapping of the Dusty Torus of AGN NGC 6418

Billy Vazquez[1], Pasquale Galiani[2], Michael W. Richmond[1], Andrew Robinson[1], Keith D. Horne[2],

Triana Almeyda[1], Mark Bottorff[3], Daniel Batcheldor[4], Bradley M. Peterson[5], Jack F. Gallimore[6], Catherine Buchanan[7], Alessandro Capetti[8], Moshe Elitzur[9], Makoto Kishimoto[10], Alesandro Marconi[11], Rachel Mason[12], Hagai Netzer[13], Christopher C. Packham[14], Enrique Perez[15], Clive Tadhunter[16], Giovanna Stirpe[17], Thaisa Storchi-Bergmann[18], John Upton[3], David Axon[1]
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The idea that the central regions of Active Galactic Nuclei (AGN) are obscured by a circum-nuclear torus of dusty molecular gas is a keystone of the AGN Unified Scheme. However, the size and structure of the torus are not well constrained by observations. Here, we present early results from an international campaign to determine the size of the torus in a sample of 12 Seyfert galaxies using reverberation mapping techniques, focussing on the Seyfert 1 galaxy NGC 6418. We have used the Spitzer Space Telescope to acquire mid infrared (3.6 and 4.5 micron) observations for over a year with a high cadence of 3 days. Optical V band observations were obtained concurrently using several ground based telescopes. Cross-correlation of the 3.6 micron and optical (V-band) light curves, indicates that the size for the region 3.6 micron-emitting region to be 30.7 +/- 2.2 light days. We also find a lag of 11.5 +/- 0.9 days between the 3.6 micron and 4.5 micron channels. We discuss the implications of these results.

251.05 – Angular Distribution of the X-ray Reflection in Accretion Disks

Javier Garcia[1], Thomas Dauser[4,5], Anne M. Lohfink[2], Timothy R. Kallman[3], Jeffrey E. McClintock[1], James F. Steiner[1], Laura Brenneman[1], Jörn Wilms[4,5], Christopher S. Reynolds[2], Francesco Tombesi[2,3]
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For the study of black holes, it is essential to have an accurate disk-reflection model with a proper treatment of the relativistic effects that occur near strong gravitational fields. These models are used to constrain the properties of the disk, including its inner radius, the degree of ionization of the gas, and the elemental abundances. Importantly, reflection models are the key to measuring black hole spin via the Fe-line method. However, most current reflection models only provide an angle-averaged solution for the flux reflected at the surface of the disk, which can systematically affect the inferred disk emission. We overcome this limitation by exploiting the full capabilities of our reflection code XILLVER. The solution of the reflected intensity of the radiation field is calculated for each photon energy, position in the slab, and viewing angle. We use this information to construct a grid of reflection models in which the inclination of the system is included as a free fitting parameter. Additionally, we directly connect the angle-resolved XILLVER model with the relativistic blurring code RELLINE to produce a self-consistent numerical model for to angular distribution of the reflected X-ray spectra from ionized accretion disks around black holes. The new model, RELCONV_XILL, is provided in the appropriate format to be used in combination with the commonly used fitting packages. An additional version of the new model, RELCONV_LP_XILL, which simulates the reflected spectra in a lampost scenario, is also supplied.

251.06 – Correlations of Circumnuclear Water Maser Luminosity with AGN Activity and SMBH Mass

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We examine 53 water masers, the only known resolvable tracers of gas in the sub-parsec disks of active galactic nuclei (AGN). We test if there is a relationship between the isotropic maser luminosity and black hole mass and AGN activity. Black

hole mass is estimated from velocity dispersion, sigma, and AGN bolometric luminosity from [OIII]5007 luminosity, from SDSS spectra. The maser are sorted, based on their radio spectra, into disk-type masers, located in the accretion disk, jet-type masers, located in a jet/outflow, or other-type masers, where the location of the masers is unclear. The maser luminosity is fit against black hole mass and AGN luminosity and compared with the theoretical predictions from Neufeld and Maloney (1995). This builds on the result from Zhu et al. (2011) with a doubled sample size and fitting for both variables at the same time. The dependence of isotropic maser luminosity of the disk and jet masers on black hole mass and AGN luminosity agree within error to the model, while the "other" masers show no correlation.

251.07 – Gas Flows in the Inner Kiloparsec of NGC 1386

Davide Lena[1], Andrew Robinson[1], Trent Seelig[1], Allan Schnorr-Muller[2], Rogemar A. Riffel[3], Thaisa Storchi-Bergmann[2], Guilherme Couto[2]
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What are the mechanisms that funnel gas from the inner kpc of an active galaxy (AGN) down to the central super-massive black hole (SMBH)? Is there any relation between the SMBH accretion rate and the mass in/outflow rate? To answer these questions we are studying a sample of nearby AGN spanning a wide range of nuclear X-ray luminosity (a proxy for the SMBH accretion rate). Here we present results of a detailed analysis of the ionized gas kinematics in the inner kpc of NGC 1386, a nearby Seyfert 2. Data have been obtained with the GMOS integral field unit on the GEMINI South telescope at a spatial resolution of ~70 pc and a spectral resolution of ~50 km/s. Previous HST narrow-band imaging observations suggested the presence of a bipolar outflow. However, our velocity maps show that these features are consistent with a rotating large-scale disk extending over ~300 pc in radius and illuminated by the AGN radiation cone, whilst the inner 100 pc is dominated by a wide-angle outflow whose axis is roughly perpendicular to the cone.

251.08 – Spitzer and Kepler Space Telescope Detection of Reverberation in the Seyfert 1 Galaxy Zw 229-015

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Near-infrared reverberation measurements have proven to be a valuable tool for mapping the location of hot dust in active galactic nuclei (AGNs). Ground-based campaigns have shown that the K-band continuum varies in response to changes in the optical continuum, and measurements of the K-band lag time give the size scale of the hot dust emission region, which likely corresponds to the dust sublimation radius. Reverberation measurements at longer wavelengths can add valuable information on the dust temperature profile in AGNs and the structure of the putative dusty torus. We have conducted a space based monitoring campaign of the Seyfert 1 galaxy Zw 229-015 using optical data from the Kepler Space Telescope and infrared data (3.6 micron) from the Spitzer Space telescope. We have also augmented the optical data with multiple ground based observatories. We have detected infrared reverberation both on short and long timescales.

251.09 – A Statistical Investigation of the Connection between X-ray and Water Maser Emission in Galaxy Centers

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Previous studies reveal a potential intimate connection between maser emission and X-ray obscuring columns in galaxy centers, with higher obscuration for more pronounced water maser activity. The number statistics involved in these investigations remain small, however. Currently, there are 151 confirmed maser detections and over 3300 surveyed non-maser galaxies. A careful crossmatch with public data from five X-ray telescope survey catalogs (the 2XMMi-DR3 from the XMM-Newton telescope, the Chandra Source Catalog, the ROSAT All-Sky Survey bright and faint source catalogs, the Swift Burst Alert Telescope 70 month survey, and the Integral IBIS 7-year All-Sky Survey) reveals X-ray information for 103 detected maser galaxies and ~650 non-detections, offering a clear statistical advantage over previous work. We are thus able to conduct a statistical comparison of the X-ray properties of the largest sample of X-ray active galaxies surveyed for water vapor emission at 22 GHz. We find that the X-ray detection rate of masers is on average 3.5 times greater than that of

non-masers, with the rates increasing in harder X-ray bands. The X-ray apparent brightness of maser and non-maser detections are similar at soft X-rays, but the maser galaxies are increasingly brighter than the non-masers in the harder bands. The X-ray luminosities calculated without correction for intrinsic absorption are lower for maser galaxies, which supports previous results showing generally higher neutral hydrogen column densities (NH) in these sources. We statistically test the potential evidence for greater obscuration in increasingly more luminous maser galaxies via monte carlo simulations of various NH distributions that are motivated by previous studies, and explore the possible physical connections that could govern them.

251.10 – The SEDs of Gapped Accretion Disks surrounding Binary Black Holes

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We calculate the observability of a black hole (BH) accretion disk with a gap or a hole created by a secondary BH embedded in the disk. We find that for an interesting range of parameters of BH masses (~10^6-10^9 M™), orbital separation (~1 AU to ~0.1 pc), and gap width (10-190 disk scale heights), the missing thermal emission from a gap manifests itself in an observable decrement in the spectral energy distribution (SED). The change in slope in the broken power law is strongly dependent on the width of the gap in the accretion disk, which in turn is uniquely determined by the mass ratio of the BHs (under our assumptions), such that it scales roughly as $q^{5/12}$. Thus, one can use spectral observations of the continuum of bright AGNs to infer not only the presence of a closely separated BH binary, but also the mass ratio. When the BH merger opens an entire hole (or cavity) in the inner disk, the broadband SED of the AGNs or quasar may serve as a diagnostic. We note future directions for this research.

251.11 – Probing Systematic Bias in the Reverberation Mapped Quasar Sample

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Black hole mass estimates of active galactic nuclei (AGN) over a wide range of redshift are an important tool for understanding the evolution of galaxies. The mass of a black hole can be measured using reverberation mapping (RM), a technique that can only be applied to bright, nearby AGN. At higher redshift, scaling relationships developed from RM AGN are applied to estimate quasar black hole masses. Richards et al. (2011) have shown that quasars display a wide range of UV emission-line properties indicative of appreciable and systematic differences in the broad emission line region. Curiously, all of the RM quasars fall within a small region of this UV parameter space. As such, we are concerned about a potential bias in extrapolating from low-L, low-z RM quasars to the average quasar. Our goal is to utilize the ratio of UV to X-ray flux, α_{ox}, to further explore and characterize any bias in the RM quasar sample. To do this, we will compare the X-ray properties of the RM sample, taken from the literature and archival Chandra data, to archival observations of existing SDSS quasars where masses have already been estimated from scaling relations. Support for this work was provided by the National Aeronautics and Space Administration through Chandra Award Number 14700216.

251.12 – The Importance of Winds for AGN Feedback

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Active galactic nuclei (AGN) are fed by accretion of matter onto supermassive black holes (SMBHs), generating huge amounts of radiation from very small volumes. AGN also provide feedback to their environments via mass outflows of ionized gas, which could play a critical role in the formation of large-scale structure in the early Universe, chemical enrichment of the intergalactic medium, and self-regulation of SMBH and galactic bulge growth. We provide an update on our research on the winds in nearby moderate-luminosity AGN, In particular, we concentrate on winds that occur on relatively large scales (hundreds of parsecs) that are revealed through spatially resolved HST spectra of emission-line gas in the narrow line regions (NLRs) of nearby AGN. We discuss the techniques for measuring the mass outflow rates and kinetic luminosities of these AGN winds and gauge their importance for providing significant AGN feedback.

251.13 – The Brightest AGN: Characterizing Their Hot Gas Environments and the Accretion of Cooling Gas Onto Their SMBHs

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Over their lifetime, AGN switch from a radiatively bright QSO phase to a radiatively dim phase, where most of their energy output is in the form of mechanical feedback. For SMBHs in the cores of galaxy clusters, it is clear cooling cluster gas is sufficient to fuel the observed AGN outbursts. However, the question of fueling an AGN outburst in a poor group environment is not so obvious. We present Chandra observations for a small sample of powerful radio sources selected from the 3CRR catalog and not in rich clusters, and compare their X-ray characteristics to their radio morphologies. We find that hot gaseous atmospheres surrounding these AGN are common, and that cooling flows are present in most of our sources. Our results indicate that cooling intracluster gas and stellar mass loss are sufficient to fuel these AGN, and that galaxy mergers are not required. In addition, our measured Eddington ratios for the SMBHs suggest that one source is in transition from radiatively bright to radiatively dim, which can provide further insight into how AGN evolve. This work was supported in part by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.

251.14 – Radiative deceleration in relativistic jets.

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We discuss radiative deceleration in the pc and kpc environments of extragalactic jets. We show that under reasonable assumptions this deceleration is not negligible and can be used to further understand the propagation of these jets.

251.15 – Investigating the emission mechanisms of the jet in the quasar PKS 1127-145

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There is currently uncertainty surrounding the emission mechanism for X-ray photons in quasar jets, with both Inverse Compton Scattering from the Cosmic Microwave Background (IC/CMB) and synchrotron models considered possibilities. We use a 100 ks observation (Siemiginowska et al 2007) of the redshift z=1.18, radio-loud quasar PKS 1127-145 taken by the Chandra X-ray Observatory, with the hope of accurately measuring the offsets between radio and X-ray radiation peaks in order to establish the emission process for this jet. PKS 1127-145 is a bright quasar with a long jet which has several bright knots and complex morphology, making it a perfect source for this investigation. We use a Bayesian statistical method called Low-Count Image Restoration and Analysis (LIRA, Connors & van Dyk 2007, Esch et al 2004) to investigate the quasar jet. This fits the parameters of a multiscale model to the data by employing a Markov Chain Monte Carlo process. LIRA has shown the location of some jet X-ray components, although further simulations must be undertaken to determine whether these are statistically significant. We also study these jet X-ray components in both hard and soft X-ray bands in order to gain more information on the energy of the emitted photons. References: Connors, A., & van Dyk, D. A. 2007, Statistical Challenges in Modern Astronomy IV, 371, 101 Esch, D.N., Connors, A., Karovska, M., & van Dyk, D.A. 2004, ApJ, 610, 1213 Siemiginowska, A., Stawarz, L., Cheung, C.C., et al. 2007, ApJ, 657, 145

251.16 – Trans-Relativistic Particle Acceleration in Astrophysical Plasmas

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Trans-relativistic particle acceleration due to Fermi interactions between charged particles and MHD waves helps to power the observed high-energy emission in AGN transients and solar flares. The trans-relativistic acceleration process is challenging to treat analytically due to the complicated momentum dependence of the momentum diffusion coefficient. For this reason, most existing analytical treatments of particle acceleration assume that the injected seed particles are already relativistic, and therefore they are not suited to study trans-relativistic acceleration. The lack of an analytical model has forced workers to rely on numerical simulations to obtain particle spectra describing the trans-relativistic case. In this work we present the first analytical solution to the global, trans-relativistic problem describing the acceleration of seed particles due to hard-sphere collisions with MHD waves. The new results include the exact solution for the steady-state Green's function resulting from the continual injection of monoenergetic seed particles with an arbitrary energy. We also introduce an approximate treatment of the trans-relativistic acceleration process based on a hybrid form for the momentum diffusion coefficient, given by the sum of the two asymptotic forms. We refer to this process as "quasi hard-sphere scattering." The main advantage of the hybrid approximation is that it allows the extension of the physical model to include (i) the effects of synchrotron and inverse-Compton losses and (ii) time dependence. The new analytical results can be used to model the trans-relativistic acceleration of particles in AGN and solar environments, and can also be used to compute the spectra of the associated synchrotron and inverse-Compton emission. Applications of both types are discussed. We highlight (i) relativistic ion acceleration in black hole accretion coronae, and (ii) the production of gyrosynchrotron microwave emission due to

relativistic electron acceleration in solar flares.

251.17 – Testing the Twisted Torus Model of Quasar Obscuration

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The Unified Scheme of AGNs uses a cold, thick torus to block our view of the nucleus from most directions. This is a theoretically implausible structure, even if clumpy. An alternative structure, which arises naturally in some scenarios for feeding supermassive black holes, is a "twisted torus", a warped thin dusty disk (Lawrence and Elvis 2010). Roseboom et al. (2013) found that this model predicted the correct, wide, distribution of hot dust covering factors for SDSS type 1 (broad-line) quasars (mean ~0.35, sigma ~0.2). Here we report the spectral energy distributions (from tahe WISE, UKIDSS/2MASS, SDSS surveys) for ~200 type 2 SDSS quasars with $0.3 < z < 0.83$ from Reyes et al. (2008), with luminosities $8.3 < \log L([OIII]) < 10$. The twisted torus model predicts a higher average covering factor (~0.65) for these objects than for a matched sample of type 1 quasars. We will present our results on this strong test of the twisted torus model.

251.18 – Tests of Excitation and Reverberation in the Sub-pc Megamaser Disks of Nearby AGN

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Contributing teams: Megamaser Cosmology Project

The edge-on circumnuclear megamaser disk in NGC 4258, well-known for enabling a direct distance measurement to its host galaxy, also displays a pronounced asymmetry in its 22 GHz maser spectrum. The redshifted high-velocity features, which arise from the midline of the disk, are notably more intense than the corresponding blueshifted features. Maoz & McKee (1998) postulate that this asymmetry is the result of maser emission emanating from trailing spiral shock fronts in the disk, which systematically weakens blueshifted emission. Recent maser surveys, mainly with the Green Bank Telescope, have detected ~30 additional megamaser disks. Here we present an analysis of the maser profiles that demonstrates that the red/blue asymmetry is not ubiquitous among megamaser disks, and that in fact NGC 4258 appears to be an outlier in this regard. As an additional component of this analysis, we employed a technique similar to the reverberation mapping of AGN to test the maser spectra for signatures consistent with radially propagating excitation. Using data collected by the Megamaser Cosmology Project, we analyzed GBT spectra of 6 galaxies, each of which was observed at a roughly monthly cadence over several years. We detected no propagating signals in any of the spectra, down to a limiting flux density of approximately 10 mJy.

251.19 – Observed Accelerations Due to Bends in Extragalactic Radio Jets

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We present the results of simulations of jets in Active Galactic Nuclei to examine the effects of simple bends on the observed accelerations of jet features. Jet features, or 'components', were modeled to have zero acceleration parallel to the jet direction, i.e. constant Lorentz factor, and only a single, instantaneous change in direction halfway through their trajectory. The apparent motions of the jet features produced by the simulation were fitted with the same simple 2-dimensional, constant acceleration models as used in the MOJAVE kinematic analysis (Lister et al. 2009, AJ v138 p1874). We find that the average magnitude of the fitted parallel accelerations was only between 50-60% of the average magnitude of the fitted perpendicular accelerations, in agreement with a prediction made by Homan et al. (2009, ApJ v706 p1253) for jets that only contain intrinsic bends and no changes in Lorentz factor. In comparing our simulated data with that of the MOJAVE observations, we find that simple bends of this type are capable of reproducing the approximate magnitude of observed accelerations perpendicular to the jet direction but cannot also explain the observed accelerations parallel to the jet direction. We conclude that both bends and intrinsic accelerations parallel to the jet direction, i.e. Lorentz factor changes, are required to produce the accelerations of the type observed in the MOJAVE sample. This work has been supported National Science Foundation grant AST-0707693. The MOJAVE program is supported under NASA-Fermi grant 11-Fermi11-0019.

251.20 – A Black Hole Recoil Candidate in a Nearby Dwarf Galaxy

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We have discovered a potential black hole recoil candidate offset from a nearby dwarf galaxy by 0.8 kpc. The object, is a point source that shows broad Balmer lines and was originally classified as a supernova because of its non-detection in 2005. We however, detect it in recent observations indicating it is still luminous and shows variability over 63 years from DSS, SDSS, and Pan-Starrs data obtained since 1950. The object shows broad Balmer, Fe II, Ca II, and He I lines consistent with classical AGN optical spectra, but offset by 300 km/s from the galaxy redshift. The observed narrow line emission is consistent with originating from host galaxy contamination. Our adaptive optics observations constrain the source size to be smaller than 10 pc, suggesting that all of the emission is coming from an extremely small region. Overall these properties are consistent with theoretical predictions of a runaway black hole caused by general relativistic effects predicted in black hole mergers.

251.21 – Quasar Outflows and AGN Feedback in the Extreme UV: HST/COS Observations of QSO HE0238-1904

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Spectroscopic observations of quasar outflows at rest-frame 500-1000 Angstrom have immense diagnostic power. We present analyses of such data, where absorption troughs from three important ions are measured: first, O IV and O IV* that allow us to obtain the distance of high ionization outflows from the AGN; second, Ne VIII and Mg X that are sensitive to the very high ionization phase of the outflow. Their inferred column densities, combined with those of troughs from O VI, N IV, and H I, yield two important results: 1) The outflow shows two ionization phases, where the high ionization phase carries the bulk of the material. This is similar to the situation seen in x-ray warm absorber studies. Furthermore, the low ionization phase is inferred to have a volume filling factor of 10^(-5)-10^(-6). 2) From the O IV to O IV* column density ratio, and the knowledge of the ionization parameter, we determine a distance of 3000 pc. from the outflow to the central source. Since this is a typical high ionization outflow, we can determine robust values for the mass flux and kinetic luminosity of the outflow: 40 solar masses per year and 10^45 ergs/s, respectively, where the latter is roughly equal to 1% of the bolometric luminosity. Such a large kinetic luminosity and mass flow rate measured in a typical high ionization wind suggests that quasar outflows are a major contributor to AGN feedback mechanisms.

251.22 – Morphology of the AGN Outflow from FBQS J0209-0438

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Spectroscopic observations of quasar outflows at rest-frame 500Å-1000Å have immense diagnostic power. Wavelength coverage of this range includes absorption troughs from OIV and OIV*, which allow us to measure the hydrogen number density through collisional excitation modeling, leading to a measurement of the outflow's distance from the central source. In the object we present, FBQS J0209-0438, such absorption troughs separate into five kinematic components, allowing for velocity-dependent photoionization modeling, and a determination of the distance-velocity relation. Through this relation, our analysis shows that the outflow from FBQS J0209-0438 has a lesser outward radial velocity at larger distances than it exhibits closer to the AGN (i.e. it is decelerating either as an outflow or infall). Absorption troughs from very highly ionized species such as NeVIII, ArVIII and MgX also appear in this spectral range and confirm the presence of two ionization phases, where the high ionization phase carries the bulk of the material. This is similar to the situation seen in x-ray warm absorber studies. These two results create a detailed schematic of the structure of this typical AGN outflow.

251.23 – Time Dependent Leptonic Modeling for the Flat Spectrum Radio Quasars: 3C 273 and 3C 279

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We highlight the results of time dependent leptonic modeling of the spectral energy distributions and light curves in different frequency bands on the flat spectrum radio quasars 3C 273 and 3C 279. Beginning with an equilibrium describing the long-term average state of the SEDs, we peform a parameter study on each blazar to determine the effects of time-dependent variations of individual parameters on the resulting snap-shot SEDs and light curves. We consider the effects of 2nd order Fermi processes, as well as synchrotron radiation losses and Compton losses of the particle population off of the internal and external radiation fields. We also consider the effects of pair production, gamma-gamma and synchrotron self-absorption.

251.24 – Self Regulated Growth of Stars and Black Holes in Galaxies via Feedback

Sydney Sherman[1], Yuexing Li[1], Qirong Zhu[1]
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It has long been suggested that feedback from stars and black holes plays an important role in galaxy formation and evolution. However, it is unclear how they affect the relations between black holes and their host galaxies. Here we investigate the effects of different forms of feedback on the mass assembly of galaxies and their black holes from an extensive observational sample that includes both AGNs and non-AGN galaxies. We find that AGN feedback plays a critical role in regulating both star formation and black hole accretion, which results in the correlation between the mass of a supermassive black hole and the stellar mass of its host galaxy.

251.25 – The ICRF3 Roadmap to the next generation International Celestial Reference Frame

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Contributing teams: ICRF-3 working group

ICRF-3 seeks to improve upon the highly successful ICRF-2. Our goals are to improve the precision, spatial and frequency coverage relative to the ICRF-2 by 2018. This date is driven by the desire to create radio frames that are ready for comparison with the Gaia optical frame. Several specific actions are underway. A collaboration has started to improve at S/X-band precision of the 2000+ VLBA Calibrator Survey sources which are typically 5 times less precise than the rest of the ICRF-2. S/X-band southern precision improvements are planned from observations with southern antennas such as the AuScope and HartRAO, S. Africa. We seek to improve radio frequency coverage with X/Ka and K-band work. An X/Ka frame of 600+ sources now has full sky coverage from the addition of a 2nd southern station in Argentina which should strengthen the southern hemisphere in general. A K-band collaboration has formed with similar coverage and southern precision goals. On the analysis front, special attention will be given to combination techniques both of VLBI catalogs and of multiple data types. Consistency of the CRF with the TRF and EOP is another area of concern. Finally, work is underway to identify and pinpoint sources bright enough in both radio and optical to allow for a robust frame tie between VLBI and Gaia optical frames.

251.26 – The Efficiency of Jet Production in Radio Galaxies

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We present an analysis of the efficiency with which the central engines of low-luminosity AGNs generate jet power (i.e. the kinetic efficiency), based on archival Chandra observations of a sample of 27 radio galaxies. These systems are relatively nearby, such that the cluster properties can be resolved at radii within an order of magnitude of the Bondi radius and the jet powers are constrained from the X-ray cavities. We explore a range of density profiles based on hot accretion flow models and estimate the kinetic efficiencies. We find that these low power (<1E45 erg/s) radio galaxies are quite efficient in generating outflowing energy in jets given the available gas supply. In particular, if there is significant mass-loss in the accretion flow as suggested by recent observations of NGC 3115 and Sgr A*, then efficiencies >50% are favored for the sample. We discuss the implications of these results in terms of jet production scenarios and the role of the black hole spin.

251.27 – Five Years of the Fermi LAT Flare Advocate

Bryce Carpenter[1, 2], Roopesh Ojha[2], Dario Gasparrini[3, 4], Stefano Ciprini[3, 4]
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Contributing teams: on behalf of the Fermi LAT collaboration; on behalf of the Fermi LAT Flare Advocates

Since the launch of the Fermi satellite, the Fermi Large Area Telescope (LAT) team has run a program that provides a daily review of the the gamma-ray sky as soon as Fermi LAT data becomes available. The Flare Advocate/Gamma-ray Sky Watcher (FA-GSW) program allows a rapid analysis of the Automatic Science Processing (ASP) products and triggers dedicated followup analyses by several LAT science groups such as those studying Galactic transients, extragalactic sources and new gamma-ray sources. Significant gamma-ray detections also trigger rapid communications to the entire astrophysical community via astronomical telegrams and gamma-ray coordination network notices. The FA-GSW program plays a key role in maximizing the science return from Fermi by increasing the rate of multi-frequency observations of sources in an active gamma-ray state. In the past ~5 years blazar flaring activity of varying strength and duty cycles, gravitationally lensed blazars, flares from Galactic sources (like Nova Delphini and the Crab Nebula), unidentified transients near and off the Galactic plane, and emission from the quiet and flaring Sun, represent the range of detections made. Flare Advocates have published about 250 Astronomical Telegrams and they publish a weekly blog. Timely, extensive multi-frequency campaigns

have been organized to follow-up on these phenomena leading to some of Fermi's most interesting results.

251.28 – Diffuse X-Ray Emission in Active and Normal Galaxies in the Extended Groth Strip

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Using data from the All Wavelength Extended Groth Strip International Survey (AEGIS) we extract X-ray emission in the interstellar medium (ISM) from active and quiescent galaxies at $0.3 \leq z \leq 0.8$ at a scale of 10-40 kpc . Comparing the stacked X-ray surface brightness profiles of active and quiescent galaxies matched in redshift, color and luminosity, we investigate the effects of feedback from active galactic nuclei (AGNs) on the diffuse gas in the ISM. We do not see any appreciable difference between the surface brightness profiles of AGNs and galaxies. Our galaxy and AGN surface brightness profiles match up with some recent theoretical models. The results tentatively suggest that AGNs are likely to have a very short term effect on the diffuse gas in the ISM. This work was partially supported by the NSF through grant number 1211112, and by NASA through ADAP award NNX12AE38G and HST-AR-1237.01-A.

252 – Starburst Galaxies Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

252.01 – Identifying the Physical Parameter Responsible for the Ionization Sequence in Star Forming Galaxies

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High ionization star forming galaxies are easily identified with strong emission line techniques such as the BPT diagram, but for ionization levels below $\log([O\ III]/H\beta) \sim 0.3$ they become confused with low-ionization AGN, making their physical interpretation difficult. Mean field independent component analysis (MFICA) is a novel approach to processing emission line spectra that can disentangle the AGN and starlight contributions to emission lines allowing the properties of pure AGN and pure starburst galaxies to be interpreted over a wide range of ionization. We applied MFICA to large sample of low-z SDSS galaxies and created subsamples of pure star forming galaxies resulting in a sequence of varying ionization. We used a locally optimally emitting (LOC) cloud model to fit emission line ratios that constrain the excitation mechanism, spectral energy distribution, abundances and physical conditions. Preliminary results in fitting diagrams that constrain the excitation mechanism indicate that the variation of starburst galaxies is due to a change in the radial distribution of clouds, rather than differences in metallicity, ionization parameter or spectral energy distribution. This confirms that MFICA is a powerful tool to assess differences in emission line properties solely due to starbursts. We briefly discuss future work that will decipher other properties in star forming galaxies.

252.02 – Imaging the Spatial Density Within Starburst Galaxies M82 and Arp220

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The derivation of the molecular hydrogen spatial density is key not only to understanding fundamental properties like galactic star formation rates, but also the evolution of starburst galaxies. A known reliable tracer of the densest regions of molecular gas in starburst galaxies is the asymmetric rotor molecule formaldehyde (H2CO). We use the Very Large Array (VLA) to image the 1(10)-1(11) and 2(11)-2(12) rotational transitions of H2CO in the starburst galaxies M82 and Arp220 to derive molecular hydrogen spatial densities and to map the dense gas as a function of position and velocity within these galaxies. Previous studies of the spatial density within galaxies used the Green Bank Telescope (GBT) to probe the H2CO signatures toward thirteen starburst galaxies (Mangum et al 2013) to a spatial resolution of 51 to 153 arcseconds. The VLA H2CO measurements reported here, made with a spatial resolution of ~7 arcseconds, allow us to begin to image the spatial densities within the starburst galaxies M82 and Arp220. We spatially resolve three dense gas components in M82, each with varying densities, physical environments and velocity structures. We also resolve Arp220's two merging nuclei as distinct velocity components. Both measurements yield new information about the physical environments and current evolutionary processes taking place in the cores of these galaxies.

252.03 – First extragalactic detection of far-infrared CH rotational lines from the Herschel Space Observatory

Naseem Rangwala[1, 2], Jason Glenn[1], Christine Wilson[3], Phil Maloney[1], Luigi Spinoglio[4], Julia R. Kamenetzky[1], Max Schirm[3], Miguel P. Santaella[4]
1. University of Colorado, Boulder, Boulder, CO, United States. 2. NASA Ames Research Center, Moffet Field, CA, United States. 3. McMaster University, Hamilton, ON, Canada. 4. Istituto di Fisica dello Spazio Interplanetario, Roma, Rome, Italy.

We present the first extragalactic detections of several CH rotational transitions in the far-infrared (FIR) in four nearby galaxies: NGC 1068, Arp 220, M 82 and NGC 253 using the Herschel Space Observatory. The CH lines in all four galaxies are a factor of 2 - 4 brighter than the corresponding HCN and HCO+ J = 6-5 lines (also detected in the same spectra). In the star formation dominated galaxies, M 82, NGC 253 and Arp 220, the CH/CO abundance ratio is low (~1E-5), implying that the CH is primarily arising in diffuse and translucent gas where the chemistry is driven by UV radiation as found in the Milky Way ISM. In NGC 1068, which has a luminous AGN, the CH/CO ratio is an order of magnitude higher suggesting that CH formation is driven by an X-ray dominated region. Our XDR models show that both the CH and CO abundances in NGC 1068 can be explained by an XDR-driven chemistry for gas densities and molecular hydrogen column densities that are well constrained by the CO observations. We conclude that the CH/CO ratio may a good indicator of the presence of AGN in galaxies. We also discuss the feasibility of detecting CH in intermediate- to high-z galaxies with ALMA.

252.04 – Molecular Gas in Starburts: Understanding Mergers using High Density Gas Tracers

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NGC 6240 and Arp 220 can be considered the founding members of a very active class of objects called Ultraluminous Infrared Galaxies or ULIRGs. They are in different stages of mergers and hence are excellent case studies to enhance our knowledge about the merging process. We have imaged the dense star-forming regions of these galaxies at sub-arcsec resolution with ALMA and CARMA. Multi-band imaging allows multilevel excitation analysis of HCN, HCO+ and CS transitions which will constrain the properties of the gas as a function of position and velocity (across line profiles). We are doing an extensive multilevel excitation analysis of the merger as a function of radius which enables in depth understanding of the gas dynamics and gas properties such as temperature and density. This in turn probes the homogeneity of the gas in the merging system and hence the regions that facilitate high star formation rates. This tandem use of CARMA with ALMA to map these systems at different merger stages will assemble a more integrated picture of the merger process. We are probing the distribution and dynamics of star forming gas and star formation activity in the dense disk structures to enable new theoretical understanding of the physics, dynamics, star formation activity and associated feedback in the most active and rapidly evolving galactic nuclei. Here we present preliminary observations of Arp 220 and NGC 6240 from ALMA and CARMA.

252.05 – IDEOS: Fitting Infrared Spectra from Dusty Galaxies

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We fit models to heavily obscured infrared spectra taken by the Spitzer Space Telescope and prepare them for cataloguing in the Infrared Database of Extragalactic Observables from Spitzer (IDEOS). When completed, IDEOS will contain homogeneously measured mid-infrared spectroscopic observables of more than 4200 galaxies beyond the Local Group. The software we use, QUESTFit, models the spectra using up to three extincted blackbodies (including silicate, water ice, and hydrocarbon absorption) and PAH templates. We present results from a sample of the approximately 200 heavily obscured spectra that will be present in IDEOS.

252.06 – A Deep Arecibo Spectral Scan of Arp 220

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A deep spectral scan of the prototype Ultra Luminous Infra-Red Galaxy (ULIRG), Arp 220, has been made over the frequency range 1.1 to 10.0 GHz using the 305-m Arecibo telescope. These new observations supersede a previous shallow scan of Arp 220 (Salter et al., 2008, Astron. J., 136, 389). The spectral lines seen in the previous scan were all re-detected with greatly improved signal-to-noise ratio. These lines include hydrogen cyanide (HCN v2=1) in absorption, formaldehyde (H2CO) in emission at 4.83 GHz, and hydroxyl (OH) in emission at 1.6 GHz and absorption at 4.7, 6.0 and 7.8 GHz. In addition, a large number of hydrogen recombination lines were detected, as was the H2CO line at 4.955 GHz, and two lines that are identified with excited transitions of methylidyne (CH) at 4.848 and 4.870 GHz. The identification of other possible detections is on-going.

252.07 – Velocity Dispersion and Kinetic Energy in CGCG048A And CGCG048B

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We observed galaxies CGCG048A and CGCG048B, two objects classified as part of bent-double radio source, using spectroscopic data obtained using the Sparsepak IFU on the WIYN 3.5m telescope in Arizona. Our goal was to extract stellar and gaseous velocity dispersions from the H and [O III] emission lines, and use this information to derive the feedback energy and mass distribution of these unusual galaxies. We derived an average velocity dispersion of 100 km/s for CGCG048A and 62 km/s for CGCG048B. From this, we were able to calculate the total kinetic energy of both galaxies and found it to be on the order of 10^53 ergs. This led us to estimate the number of supernovae that could have occurred in these galaxies, and therefore conclude that these galaxies are most likely starburst, a conclusion supported by our analysis of their radio continuum emission. Our examination of the optical images suggest that these galaxies are interacting.

252.08 – Do Cosmic Rays Sample the Mean ISM Density of Starburst Galaxies?

Erin Boettcher[1], Ellen G. Zweibel[1], Tova Yoast-Hull[1], John S. Gallagher[1]
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In studies of interacting cosmic rays and the interstellar medium (ISM) in starburst galaxies, it is often assumed that cosmic rays sample the mean density of the ISM. However, given the very high galactic wind speeds and the very small filling factors of fragmented molecular clouds, this is far from a foregone conclusion in starburst environments. Here, we use Monte Carlo simulations to assess the assumption that cosmic rays sample the mean density of a two-phase ISM consisting of molecular clouds embedded in a hot, low density medium. We simulate cosmic ray propagation in a tangled magnetic field with vertical advection and a variety of injection scenarios in a medium with properties similar to those of the prototypical starburst galaxy M82. The ratio of the sampled density to the mean density is calculated by comparing the gamma-ray emissivity from pion production in molecular clouds implied by our simulations and by cosmic ray sampling of the mean density. This ratio remains close to unity over a wide range of conditions on the number of molecular clouds, the galactic wind speed, the magnetic field geometry, and the cosmic ray injection mechanism. However, this ratio becomes elevated by a factor of a few when the cosmic rays are injected close to a small number of dense molecular clouds in the presence of a very tangled magnetic field. Using the results of our simulations, we evaluate the cosmic ray calorimeter model for starburst galaxies, and we argue that our simulated starburst region is at best a partial proton calorimeter. We acknowledge the support of NSF AST-0907837 and NSF PHY-0821899.

252.09 – Exploring the Dust Content of Galactic Winds with Herschel: Nearby Dwarf Galaxies

Alexander McCormick[1], Sylvain Veilleux[1], Marcio Melendez[1], Jonathan Bland-Hawthorn[2], Gerald Cecil[3], Chad Engelbracht[4], Fabian Heitsch[3], Crystal L. Martin[5], Thomas Mueller[6], David Rupke[7], Margaret Trippe[8], Jordan Zastrow[9]
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Galactic-scale winds manifest as the "smoking gun" of negative feedback, an essential mechanism for understanding galaxy evolution. Negative feedback has been invoked to resolve a number of issues: the mass-metalicity relation of star-forming galaxies, the tight bulge - black hole mass relation, and the presence of metals in galaxy halos and the intergalactic and intracluster media. Although negative feedback may assert even greater influence at high redshift, where strong starbursts and active galactic nuclei are more commonplace, nearby sources provide the best opportunities for detailed observations of the resultant winds. In recent years, observations have begun to illuminate the less obvious components of galactic-scale winds, including dust and molecular gas. Investigating the spatial distribution and properties of the dust in concert with host galaxy characteristics will give insight into the physics of dust entrainment, outflow energetics, and why the dust survives far outside the host galaxy. We will present results from new, deep Herschel observations of several nearby dwarf galaxies with known galactic-scale winds. Our results will compare flux measurements and the spatial distribution of cold dust in the outflows with star formation properties of the host galaxies. We will also compare these new observations with archival Spitzer and previous H-alpha observations.

252.10 – Exploring the Dust Content of Galactic Winds with Herschel: NGC 3079 and NGC 4631

Marcio Melendez[1], Sylvain Veilleux[1], Alexander McCormick[1], Crystal L. Martin[2], Chad Engelbracht[5], Jonathan Bland-Hawthorn[3], Gerald Cecil[4], Fabian Heitsch[4], Thomas Mueller[6], David Rupke[7], Margaret Trippe[1], Jordan Zastrow[8]
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There is direct and indirect evidence that cold dust (T< 100 K) may be present in the outflow of some starburst galaxies. However, the geometry, energy and mass of this dusty superwind is virtually unknown in the far-infrared wavelengths (70--500 μm). In particular there are crucial questions regarding these super-winds: what are the physical conditions under which the gas and dust finds itself? what is the extent of the dust and gas and the importance for its survival? what is the

nature of the turbulence boundary arising from the wind interaction? We present a detail analysis and comparison of very deep far-infrared observations of two nearby Starburst galaxies, NGC 3079 and NGC 4631. We compare the dust distribution between our Herschel images, Spitzer IRAC 4.5 and 8 μm and, MIPS 24 μm. We examine the dust physical properties in the wind and halo of these galaxies.

252.11 – Numerical Models of Starburst Galaxies: A Study of Outflows and ISM Morphology in Galactic Cores

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Starbursts and AGN winds in galaxy cores can produce large scale outflows. Whether any given outburst can create an outflow depends on several variables including the rate at which the energy is injected into the interstellar medium (ISM), the distribution of clouds with in the ISM, and the overall shape of the ISM. Previous simulations by Cooper et al. (2008) reproduce linear filaments like that in M 82, but were limited in the parameter space that they could explore. We have modified the public Athena hydro code (Stone et al. 2008) to greatly reduce the computation time of high resolution 3D simulations similar to Cooper et al. (2008) and to handle accurate gas cooling down to lower molecule-forming temperatures (10 K). We are exploring the parameter space of a galactic "blowout", the origin and evolution of interesting ISM morphology such as the curved filamentary "towers" observed at the center of NGC 3079, and how different ISM morphologies may influence the outflow. These simulations are being compared with spectral imaging obtained with the Herschel space telescope to study the connection between regions of the cold neutral medium, warm neutral medium, and warm ionized medium. Those observations are being presented in another session of this AAS meeting. Our work is supported by NASA/Herschel and NC Space Grant funding.

252.12 – What Do Star Clusters in Nearby Starburst Galaxies Tell Us?

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Nearby starburst galaxies are a good laboratory for the study of starburst processes. M82, one of the most famous starburst galaxies, has been a target for numerous studies of starburst events. Especially, many studies have used star clusters as starburst tracers in M82, but they usually investigated a only small central region. We present a photometric study of star clusters in M82 using wide-field *UBVI*, *YJ*, and *H* band images in the Hubble Space Telescope archive. We find ?1100 star clusters in 12'x8' field, and estimate ages and masses of about 630 star clusters using spectral energy distribution fitting method. Young star clusters are located in the disk region, while old star clusters are found in both disk and halo regions. Age distribution of star clusters shows three distinguished populations: young (? 5 Myr), intermediate-age (about 500 Myr), and old (?10 Gyr) star clusters. Several massive young star clusters ($??10^5 M_{TM}$) are found in the nuclear region, which are regarded as a result of recent starburst. Interestingly, we also find very massive star clusters ($??10^6 M_{TM}$) with intermediate-age in the nuclear region, which indicates another starburst event at about 500 Myr ago. This suggests that there are at least two starburst events: 5 Myr and 500 Myr ago, and that the earlier starburst at about 500 Myr ago may be more violent than the recent one. We also find about 30 star clusters in the halo region of M82. They are probably metal-poor old globular clusters belonging to M82 halo. It suggests that starburst galaxies may also be enshrouded by old stellar populations.

252.13 – Imaging Arp 220 in CO 6-5 and dust at 100 pc resolution with ALMA

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We present ALMA Cycle 0 observations of the prototypical ultraluminous infrared galaxy Arp 220 in the CO 6-5 line and 440 micron continuum. With a resolution of ~100 pc, the two nuclei in this merger remnant are each resolved, both in the continuum and in the line. We constrain the gas density and dynamical mass in each nucleus and compare our results to previous work on Arp 220. We also discuss an unusual offset between the CO and the dust emission peaks, as well as absorption features seen in the data.

252.14 – He II-Emitting Galaxies

Sara R. Heap[1]

1. NASA's GSFC, Greenbelt, MD, United States.

A small fraction of star-forming galaxies at redshift, z~3, show He II at 1640 A as a narrow emission line (Cassata et al. 2012), but the source of this emission is not understood. Does the He II emission arise in the stars or in the surrounding nebula? To answer this question, we use I Zw 18, a well studied blue compact dwarf galaxy showing narrow He II line emission as a test case. We consider if/how He II narrow emission lines could originate in the nearby nebulosity, or in the winds of hot, massive stars, both those on the main sequence and post-MS evolutionary phases.

252.15 – Far Infrared Fine Structure Lines in Ultraluminous Infrared Galaxies

Duncan Farrah[1]
1. Virginia Tech, Blacksburg, VA, United States.

Ultraluminous Infrared Galaxies are a cornerstone population for understanding the assembly history of galaxies at high redshift. ULIRGs at low redshift thus serve as invaluable laboratories for understanding the nature of star formation in these extreme systems. With this goal in mind, we present observations of four far-IR fine-structure lines in 25 ultraluminous infrared galaxies at z < 0.27. The lines, [O I]63, [N II]122, [O I]145, and [C II]158, all show a deficit in their line luminosity to total IR luminosity ratios, compared to lower luminosity systems. The majority of the line deficits are consistent with dustier H II regions, but part of the [C II] deficit may arise from an additional mechanism, plausibly charged dust grains. This is consistent with some of the [C II] originating from photodissociation regions or the interstellar medium (ISM). We derive relations between far-IR line luminosities and both the IR luminosity and star formation rate. We find that [N II] and both [O I] lines are good tracers of the IR luminosity and star formation rate. In contrast, [C II] is a poor tracer of the IR luminosity and star formation rate, and does not improve as a tracer of either quantity if the [C II] deficit is accounted for. We discuss some implications from these results for studies of high redshift ULIRGs.

252.16 – Hinge Clumps in Interacting Galaxies: Extra-Nuclear Starbursts

Beverly Smith[1], Roberto Soria[2], Curtis Struck[3], Mark Giroux[1], Douglas A. Swartz[4], Mihoko Yukita[5]
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Hinge clumps are luminous knots of star formation found at the base of tidal features in some interacting galaxies. We use archival Hubble Space Telescope UV/optical/IR images and Chandra X-ray maps along with GALEX UV, Spitzer IR, and ground-based optical/near-IR images to investigate the star forming properties of hinge clumps in a small sample of nearby interacting galaxies. The most extreme of these hinge clumps have star formation rates of 1- 9 solar masses per year, more than that of many normal spiral galaxies. In the HST images, we found remarkably large (~70 pc) and luminous sources at the centers of these hinge clumps. If these are individual star clusters they would lie near the top of the `super star cluster' luminosity function of star clusters; alternatively, they may be tightly packed groups of clusters blended together in the HST images. These sources are sometimes embedded in a linear ridge of fainter star clusters, consistent with star formation along a narrow caustic. Comparison to population synthesis modeling indicates that hinge clumps contain a range of stellar ages, consistent with expectations based on models of galaxy interactions, which suggest that star formation may be prolonged in these regions. In the Chandra images, we found strong X-ray emission from several of these hinge clumps. In most cases, this emission is well-resolved with Chandra and has a thermal X-ray spectrum, thus it is likely due to hot gas associated with the star formation. Two of the hinge clumps have point-like X-ray emission much brighter than expected for hot gas; these sources are likely `ultra-luminous X-ray sources' (ULXs) due to accretion disks around black holes. The most extreme of these point sources, in Arp 240, has a hard X-ray spectrum and an absorbed X-ray luminosity greater than 10^41 erg/s, above the luminosity expected by a single high mass X-ray binary. thus it may be either a collection of HMXBs or an intermediate-mass black hole.

252.17 – Probing star formation in local luminous compact blue galaxies

Katherine Rabidoux[1], Daniel J. Pisano[1, 2], Amanda A. Kepley[2], Kelsey E. Johnson[3, 4]
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Luminous compact blue galaxies (LCBGs) are a heterogeneous class of galaxies that are currently experiencing a burst of star formation. While they were common at z~1, they are an order of magnitude rarer in the local universe. This discrepancy implies that this type of galaxy is a transient phase; these galaxies must evolve relatively rapidly. While it is known that LCBGs must stop forming stars in the near future and subsequently evolve, it is not known when their star formation ends, what processes cause the quenching, and what these galaxies become. To probe the global properties of the galaxies' starbursts, we have observed 40 local (D < 80 Mpc) LCBGs with the Caltech Continuum Backend and MUSTANG bolometer array on the Green Bank Telescope at frequencies where tracers of very recent star formation are strong. When this data is combined with archival observations at radio and infrared wavelengths, we can form a picture of the recent star formation

histories of these galaxies. In modeling LCBGs' SEDs, we can constrain their timescales of recent star formation and correlate their star formation properties with other known properties of LCBGs. From analysis of these properties and timescales, we can determine the likelihood of their star formation continuing at its current pace, and thus constrain their evolutionary paths.

252.18 – Constraining Stellar Feedback: Shock–ionized Gas in Nearby Starburst Galaxies

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We investigate the properties of feedback-driven shocks in 8 nearby starburst galaxies using narrow–band imaging data from the Hubble Space Telescope. We identify the shock–ionized component via the line diagnostic diagram [O III](λ5007)/Hβ vs. [S II]($\lambda\lambda$6716,6731)(or [N II](λ6583))/Hα, applied to resolved regions 3–15 pc in size. We divide the sample into three sub–samples: sub– solar, solar and super–solar for consistent shock measurements. For the sub–solar sub–sample, we derive two important (but, tantalizing) scaling relations: (1) Lshock ? SFR^0.62 and (2) Lshock/ Ltot ? (LH/L™,H)^0.65, where Lshock is the Hα luminosity from shock–ionized gas and L_tot the total Hα luminosity, and LH/L™,H the absolute H-band luminosity from 2MASS normalized to solar luminosity. The scaling relations are similar to those by Hopkins et al. (2012) for galactic super winds. This similarity should, however, be taken with caution at this point, as the underlying physics that enables the transition from radiative shocks to gas outflows in galaxies is still poorly understood.

252.19 – Age-Dating Star Clusters in the Luminous Infrared Galaxy VV340

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1. Howard University, Washington DC, DC, United States.

The luminous infrared galaxy (LIRG: i.e., L_IR [8-1000 microns] >~ 10^11 L_sun) VV 340 is observed to be a pair of z = 0.03 interacting spiral galaxies, with one being observed face-on (VV340North) and one edge-on (VV 340South). The interaction has triggered a burst of star formation in both galaxies, and we make use of Hubble Space Telescope ultraviolet (ACS/SBC) and optical (ACS/WFC) imaging data to constrain the age of luminous optical clusters in the face-on galaxy VV 340South. We find that, for an instantaneous starburst, a Salpeter IMF and no reddening, the cluster ages are in the range of 10-300 million years old. However, the clusters can be a young as a few million years with significant amounts of reddening. The upper limit cluster age range is consistent with detailed modeling of a subset of LIRGs which show that pericentric passage in many LIRGs occurred 200-500 million years prior to when these systems are being observed. This study is part of the Great Observatories All-sky LIRG Survey (GOALS), which is a multi-wavelength campaign designed, in part, to study the evolution of star formation in LIRGs.

252.20 – The Properties of submm Galaxies in the CANDELS GOODS-S Field -- Combining ALMA with HST

Tommy Wiklind[1]
1. European Southern Observatory, Santiago, Vitacura, Chile.
Contributing teams: CANDELS Team

We derive physical properties of 10 submillimeter galaxies located in the CANDELS coverage of the GOODS-S field. The galaxies were first recognized as submillimeter sources with the LABOCA bolometer and subsequently targeted for 870um continuum observation with ALMA. The high angular resolution of the ALMA imaging allows secure counterparts to be identified in the CANDELS multiband dataset. The CANDELS data provide deep and accurate photometric data from UV through near-infrared wavelengths. Using synthetic spectral energy distributions based on CANDELS photometry, we derive photometric redshifts, stellar masses, dust extinction, age estimates, and a description of the star formation history of these submillimeter galaxies.

253 – Astroinformatics and Astrostatistics Poster Session
Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

253.01 – AstroML: Python-powered Machine Learning for Astronomy

Jake Vander Plas[1], Andrew J. Connolly[1], Zeljko Ivezic[1]
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As astronomical data sets grow in size and complexity, automated machine learning and data mining methods are becoming an increasingly fundamental component of research in the field. The astroML project (http://astroML.org) provides a common repository for practical examples of the data mining and machine learning tools used and developed by astronomical researchers, written in Python. The astroML module contains a host of general-purpose data analysis and machine learning routines, loaders for openly-available astronomical datasets, and fast implementations of specific computational methods often used in astronomy and astrophysics. The associated website features hundreds of examples of these routines being used for analysis of real astronomical datasets, while the associated textbook provides a curriculum resource for graduate-level courses focusing on practical statistics, machine learning, and data mining approaches within Astronomical research. This poster will highlight several of the more powerful and unique examples of analysis performed with astroML, all of which can be reproduced in their entirety on any computer with the proper packages installed.

253.02 – The Astrostatistics and Astroinformatics Portal

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The Astrostatistics and Astroinformatics Portal (ASAIP, http://asaip.psu.edu) is a Web resource started in 2012 to foster research into advanced methodologies for astronomical research, and to promulgate such methods into the broader astronomy community. It provides searchable abstracts to Recent Papers in the field, several discussion Forums, various resources for researchers, brief Articles by experts, lists of Meetings, and access to various Web resources such as on-line courses, books and blogs. The material can be electronically searched. The site will be used for public outreach by organizations associated with the AAS, IAU, ISI (International Statistical Institute), and LSST. ASAIP has nearly 700 members who can contribute material, and its resources are readable by the general Web public. This presentation gives examples of recent ASAIP entries and encourages AAS members to use its resources.

253.03 – Adventures in Modern Time Series Analysis: From the Sun to the Crab Nebula and Beyond.

Jeffrey Scargle[1]
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With the generation of long, precise, and finely sampled time series the Age of Digital Astronomy is uncovering and elucidating energetic dynamical processes throughout the Universe. Fulfilling these opportunities requires data effective analysis techniques rapidly and automatically implementing advanced concepts. The Time Series Explorer, under development in collaboration with Tom Loredo, provides tools ranging from simple but optimal histograms to time and frequency domain analysis for arbitrary data modes with any time sampling. Much of this development owes its existence to Joe Bredekamp and the encouragement he provided over several decades.Sample results for solar chromospheric activity, gamma-ray activity in the Crab Nebula, active galactic nuclei and gamma-ray bursts will be displayed.

253.04 – The Virtual Observatory for the Python Programmer

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Contributing teams: US Virtual Astronomical Observatory

The web of astronomical data centers that we refer to as the virtual observatory (VO) has led to the development of a variety of web and desktop applications that can discover and download data from most archives around the world. These are made possible by standard interfaces which archives provide and the applications understand that provide a common way to search for information and retrieve discovered datasets. For some applications, retrieving data through the VO is simply an extra feature that enhances the main purpose of the tool. Despite the accessibility to VO data provided by such tools, the VO offers greater flexibility to developers that access the standard services directly within their own software. This applies not only to those who build tools but also to research astronomers that create highly-customized scripts for data analysis. One of the goals of the US Virtual Astronomical Observatory (VAO) project is to make the VO more accessible to both tool developers

and astronomer-programmers. To this end, we announce the release of two products with a special focus on supporting access to the VO via Python. PyVO (http://dev.usvao.org/pyvo) is a pure Python library built on Astropy (astropy.org) that can be used to discover data in the VO. In particular, one can search the registry for archives with data, search archives for images and spectra, and query remote catalogs and spectral line databases. While it provides full support for the VO standards, its API is designed to make processing the most common types of queries simple without requiring knowledge about the underlying standards. It also makes available the full power of Astropy for processing tabular information. VOClient (http://dev.usvao.org/voclient), which provides scripting and programming libraries for a variety of languages, also supports Python programming. While the two products share a common API, VOClient provides higher level interfaces that assist with managing data from many archives. It also features support for SAMP, a protocol that can be used to drive other desktop tools such Topcat and Aladin from a Python script. Finally, it provides a framework for making compiled legacy software callable from Python.

253.05 – Filtergraph: A fast, intuitive, online data visualization system for large astronomy datasets

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We present Filtergraph as a web application designed to rapidly and intuitively visualize large datasets. The user loads a dataset in a variety of supported file types into Filtergraph, which automatically generates an interactive data portal that can be easily shared with others. From this portal, the user can immediately generate scatter plots of up to 5 dimensions as well as histograms and tables based on the dataset. Key features of the portal include intuitive controls with auto-completed variable names, the ability to filter the data in real time through user-specified criteria, the ability to select data by dragging on the screen, and the ability to perform arithmetic operations on the data in real time. To enable seamless data visualization and exploration, changes are quickly rendered on screen and visualizations can be exported as high quality graphics files or shared as simple URLs. The application is optimized for speed: for instance, a plot generated from a database of 3.1 million entries renders in less than 2 seconds on a standard web server platform, allowing rapid-fire exploration of massive datasets with little time cost. Filtergraph is free to use at http://filtergraph.vanderbilt.edu/.

253.06 – NED in the Era of Very Large Extragalactic Surveys

Dario Fadda[1], Joseph M. Mazzarella[1], Patrick M. Ogle[1], Barry F. Madore[1], Rick Ebert[1], Kay Baker[1], Hiu Pan Chan[1], Xi Chen[1], Cren Frayer[1], George Helou[1], Jeffery D. Jacobson[1], Cheryl LaGue[1], Tak M. Lo[1], Olga Pevunova[1], Marion Schmitz[1], Scott Terek[1], Ian Steer[2]

1. CalTech, Pasadena, CA, United States. 2. Toronto, Toronto, ON, Canada.

The NASA/IPAC Extragalactic Database (NED) is in the process of rapid expansion both from the growth of the astrophysics literature and from very large sky surveys containing hundreds of millions of objects. Over the last year alone, over 3 million objects from more than 5 thousand journal articles have been folded into NED. In the same time period, approximately 60 million UV sources from the GALEX All-Sky Survey and Medium Imaging Survey catalogs have been fully integrated into the database. A new data processing approach has been developed to fold in very large catalogs. Firstly, a new NED layer is created to contain the entries from a catalog. Subsequently, the new entries are cross-matched with existent NED objects following a rule-based statistical approach. This new layer currently contains approximately 500 million near-infrared sources from the 2MASS Point Source Catalog. In future releases, we expect to fully integrate this catalog while loading a new layer of hundreds of millions of sources from the new All-WISE survey. To make accessible this wealth of new data, NED is undergoing a major user interface upgrade. As a result of a "near-position" search, the new interface is able to display sources from very large catalogs which have not yet been cross-matched with other NED objects. Navigation and searches have been simplified and enriched. For instance, the "by-parameters" search has been completely revamped and long searches are now queued and executed in the background. The latest release includes a new tool to explore galaxy environments and a guide for authors documenting the best practices to publish data in the major astrophysical journals. Researchers are encouraged to visit the NED exhibit for a demonstration of these and other new capabilities.

253.07 – Spectroscopic and Photometric Variability in the A0 Supergiant HR 1040

David Corliss[1], Nancy D. Morrison[1], Saul J. Adelman[2]

1. University of Toledo, Toledo, OH, United States. 2. The Citadel, Charleston, SC, United States.

A longitudinal time series analysis of spectroscopic and photometric variability of the A0Ia supergiant HR 1040 has been performed, including equivalent widths, radial velocities and Strömgren photometric indices. The data, obtained from 1993 through 2007, include 152 spectroscopic observations from the Ritter Observatory and 269 Strömgren photometric observations from the Four College Automated Photoelectric Telescope (FCAPT). Typical of late B- and early A-type

supergiants, HR 1040 has a highly variable stellar wind. The star was found to have an intermittent active phase marked by correlation between the Hα absorption equivalent width and blue-edge radial velocity and photospheric connections observed in correlations to equivalent widths, second moment and radial velocity in the Si II λλ6347, 6371 lines. Variable Hα emission components were also studied, along with nearby weak absorption lines Mg II λ 6546 and C II λλ 6578, 6583. High-velocity absorption (HVA) events were observed only during this active phase. HVA events in the wind were preceded by photospheric activity, including Si II radial velocity oscillations similar in form to a Morlet wavelet 19 to 42 days prior to onset of an HVA and correlated increases in Si II equivalent width and second moment from 13 to 23 days before the start of the HVA. In the photometric data, the y magnitude is found to be strongly correlated the Si II observables, indicating a possible relationship between photometric changes and the variable microturbulence. While increases in various line equivalent widths in the wind prior to HVA events have been reported in the past in other stars, our finding of precursors in radial velocity variations in the wind and at the photosphere and intervals of increased photospheric microturbulence is a new result.

253.08 – Managing the Big Data Avalanche in Astronomy - Data Mining the Galaxy Zoo Classification Database

Kirk D. Borne[1]

1. George Mason Univ., Fairfax, VA, United States.

We will summarize a variety of data mining experiments that have been applied to the Galaxy Zoo database of galaxy classifications, which were provided by the volunteer citizen scientists. The goal of these exercises is to learn new and improved classification rules for diverse populations of galaxies, which can then be applied to much larger sky surveys of the future, such as the LSST (Large Synoptic Sky Survey), which is proposed to obtain detailed photometric data for approximately 20 billion galaxies. The massive Big Data that astronomy projects will generate in the future demand greater application of data mining and data science algorithms, as well as greater training of astronomy students in the skills of data mining and data science. The project described here has involved several graduate and undergraduate research assistants at George Mason University.

254 – Surveys and Large Programs Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

254.01 – The HST Frontier Fields

Jennifer Lotz[1], Matt Mountain[1], Norman A. Grogin[1], Anton M. Koekemoer[1], Peter L. Capak[2], Jennifer Mack[1], Dan A. Coe[1], Elizabeth A. Barker[1], David S. Adler[1], Roberto J. Avila[1], Jay Anderson[1], Stefano Casertano[1], Carol A. Christian[1], Shireen Gonzaga[1], Henry C. Ferguson[1], Andrew S. Fruchter[1], Helmut Jenkner[1], Ian J. Jordan[1], Derek Hammer[1], Bryan Hilbert[1], Brandon L. Lawton[1], Janice C. Lee[1], Ray A. Lucas[1], John W. MacKenty[1], Maximilian J. Mutchler[1], Sara Ogaz[1], Iain N. Reid[1], Patrica Royle[1], Massimo Robberto[1], Kenneth Sembach[1], Linda J. Smith[1], Josh Sokol[1], Jason A. Surace[2], Denise Taylor[1], Jason Tumlinson[1], Alex Viana[1], Robert E. Williams[1], William Workman[1]
1. STScI, Baltimore, MD, United States. 2. SSC, Pasadena, CA, United States.

Using Director's Discretionary observing time, HST is undertaking a revolutionary deep field observing program to peer deeper into the Universe than ever before. The Frontier Fields will combine the power of HST with the natural gravitational telescopes of high-magnification clusters of galaxies to produce the deepest observations of clusters and their lensed galaxies and the second-deepest observations of blank fields ever obtained. Up to six strong-lensing clusters (Abell 2744, MACSJ0416.1-2403, MACSJ0717.5+3745, MACSJ1149.5+2223, AbellS1063, and Abell 370) will be targeted with coordinated parallels of adjacent blank fields with ACS/WFC and WFC3/IR cameras to ~29th ABmag depths in seven bandpasses over the next three years. These observations will reveal distant galaxy populations ~10-100 times fainter than any previously observed, and improve our statistical understanding of galaxies during the epoch of reionization. Here we present Hubble Space Telescope observations of the first set of the Frontier Fields, Abell 2744, and describe the HST Frontier Fields observing strategy and schedule. All data for this observing program is nonproprietary and available immediately upon entry into the Mikulski Archive for Space Telescopes.

254.02 – The HST Frontier Fields: Science Data Pipeline, Products, and First Data Release

Anton M. Koekemoer[1], Roberto J. Avila[1], Derek Hammer[1], Jennifer Mack[1], Sara Ogaz[1], Jay Anderson[1], Elizabeth A. Barker[1], Bryan Hilbert[1], Shireen Gonzaga[1], Norman A. Grogin[1], Andrew S. Fruchter[1], Jennifer Lotz[1], Ray A. Lucas[1], Matt Mountain[1], Josh Sokol[1]
1. STScI, Baltimore, MD, United States.

We present the first data release of the Hubble Space Telescope Frontier Fields program, a new Director's Discretionary program to carry out ultra-deep observations of six lensing clusters and parallel deep blank fields, probing the most distant galaxies currently observable. During the three-year program, each cluster is being observed for 140 orbits over two epochs, probing to 29th magnitude. We present here the first epoch of the cluster Abell 2744, observed to 70 orbits on the main cluster with WFC3/IR (in F105W, F125W, F140W and F160W) and on the parallel field with ACS (in F435W, F606W, F814W). We present the design of the pipeline for the data processing and calibration, including a new approach to ACS self-calibration. We discuss the various data products that we are distributing as high-level science products through the Mikulski Archive for Space Telescopes (MAST) at STScI, including distortion-corrected "drizzled" mosaics in all the filters, released throughout the course of the observations, as well as the final full-depth mosaics and related products. We deliver these high-level science products to the community on a rapid timescale to enable the widest scientific use of these data, as well as ensuring a public legacy dataset of the highest possible quality that is of lasting value to the entire community.

254.03 – The HST Frontier Fields: DrizzlePac Workflow

Roberto J. Avila[1], Derek Hammer[1], Jennifer Mack[1], Andrew S. Fruchter[1], Anton M. Koekemoer[1], Jay Anderson[1], Elizabeth A. Barker[1], Bryan Hilbert[1], Shireen Gonzaga[1], Norman A. Grogin[1], Jennifer Lotz[1], Ray A. Lucas[1], Matt Mountain[1], Sara Ogaz[1], Josh Sokol[1]
1. Space Telescope Science Institute, Baltimore, MD, United States.

We demonstrate the power and usability of the DrizzlePac image processing tools developed at the Space Telescope Science Institute. These tools are available to the astronomical community, to align, distortion-correct, and combine stacks of images such as the Frontier Fields mosaics. Using 'cosmic-ray cleaned' images, we test various techniques for producing source catalogs to refine the image alignment. We present methodology for aligning images across visits, across filters, across detectors, and finally to an absolute reference catalog. The alignment solutions, or 'headerlet' files, will be made available to community as 'High Level Science Products' which may be applied to archival data in order to reduce the amount of work needed to re-process the Frontier Fields dataset. We also describe methodology for optimizing the drizzling 'pixfrac' (or drop

size) of the final image for any given plate scale in order to provide the best signal-to-noise trade-off between pixel sampling and background noise.

254.04 – The HST Frontier Fields: Gravitational Lensing Models Release

Dan A. Coe[1], Jennifer Lotz[1], Priyamvada Natarajan[2], Johan Richard[3], Adi Zitrin[4], Jean-Paul Kneib[5], Harald Ebeling[6], Keren Sharon[7], Traci Johnson[7], Marceau Limousin[8], Marusa Bradac[9], Austin Hoag[9], Benjamin Cain[9], Julian Merten[10], Liliya L. Williams[11], Kevin Sebesta[11], Massimo Meneghetti[12], Anton M. Koekemoer[1], Elizabeth A. Barker[1]

1. STScI, Baltimore, MD, United States. 2. Yale, New Haven, CT, United States. 3. CRAL Lyon, Lyon, France. 4. Caltech, Pasadena, CA, United States. 5. EPFL Lausanne, Lausanne, Switzerland. 6. IfA, University of Hawaii, Honolulu, HI, United States. 7. University of Michigan, Ann Arbor, MI, United States. 8. LAM Marseille, Marseille, France. 9. UC Davis, Davis, CA, United States. 10. JPL/Caltech, Pasadena, CA, United States. 11. University of Minnesota, Minneapolis, MN, United States. 12. INAF/INFN Bologna, Bologna, Italy.

The Hubble Frontier Fields (HFF) is a Director's Discretionary Time (DDT) program to deeply observe up to six massive strong-lensing galaxy clusters and six "blank" fields in parallel. These complementary observations will yield magnified and direct images of some of the most distant galaxies yet observed. The strongly lensed images will be our deepest views of our universe to date. Interpretation of some (but not all) observed properties of the strongly lensed galaxies requires gravitational lens modeling. In order to maximize the value of this public dataset to the extragalactic community, STScI commissioned five teams funded by NASA to derive the best possible lens models from existing data. After coordinating to share observational constraints, including measured redshifts of strongly lensed galaxies, the teams independently derived lens models using robust, established methodologies. STScI released these models to the community in October before HFF observations of the first cluster, Abell 2744. Here we describe these models as well as a web tool which allows users to extract magnification estimates with uncertainties from all models for any galaxy strongly lensed by a HFF cluster. Inputs are the galaxy's coordinates (RA and Dec), redshift, and (optionally) observed radius. We also discuss ongoing work to study lens model uncertainties by modeling simulated clusters.

254.05 – The Frontier Field Supernova Survey

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Contributing teams: The FrontierSN Team

The Frontier Fields program presents an extraordinary opportunity for the detection of high redshift supernovae (SNe). The combination of very deep imaging in each epoch with the added boost from gravitational lensing magnification will provide the means to detect both Type Ia SNe (SNIa) and core collapse SNe (CC SNe) out to z~3. In our FrontierSN program we expect to discover ~50 new SNe over the entire 3-year program, including ~6 SNIa at z>1.5 and ~9 with strong lensing magnification. These samples are small but special: the high-z SNIa set has unique leverage for testing SNIa progenitor models through the delay time distribution; the lensed SNIa offer a chance to validate cluster mass models by directly measuring the lensing magnification. Our HST follow-up program will provide the color and light curve information necessary to unlock the great science potential of these SNe.

254.06 – First results from the HST Grism Lens-Amplified Survey from Space (GLASS)

XIN WANG[1], Kasper B. Schmidt[1], Tommaso Treu[1]
1. University of California, Santa Barbara, Santa barbara, CA, United States.
Contributing teams: GLASS team

GLASS is a cycle-21 large program with the Hubble Space Telescope, targeting 10 massive clusters, including the 6 Frontier Fields, using the WFC3 and ACS grisms. The program consists of 140 primary orbits and 140 parallel orbits. Using the clusters as cosmic telescopes, GLASS is taking spectra of faint background galaxies with unprecedented sensitivity and angular resolution. GLASS has 3 primary science drivers, although a variety of other science investigations are possible in combination with existing and planned imaging campaigns. The first key science goal is to shed light upon the role of galaxies in reionizing the universe, the topology of high redshift intergalactic/interstellar medium and Lyman alpha escape fraction. The second key science goal is to study gas accretion, star formation and outflows by mapping spatially resolved star formation and metallicity gradients in galaxies at z=1.3-2.3. The third key science goal is to study the environmental dependence of galaxy evolution, by mapping spatially resolved star formation in galaxies in the cluster cores and infalling regions. We present the details of the program and results from the first cluster observed by GLASS MACS0717.5+3745.

254.07 – The Ultraviolet Frontier: Deep near-UV imaging of the Hubble Frontier Fields

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We present a 48 orbit cycle-21 program to image three of the four Hubble Frontier Fields at near-ultraviolet wavelengths. Each lensing cluster will be observed for eight orbits in both the F275W and F336W filters. The primary science goals are to measure the luminosity functions of faint star-forming galaxies at 1.5<z<3, measure the Lyman continuum escape fractions, and study the sizes of star forming regions in galaxies at z~1. Observations will likely begin in October. We will present the first images and compare to the existing optical Hubble images. In addition, we will show previous results from a deep near-UV imaging program in Abell 1689 as a demonstration of what can be done with these observations.

254.08 – Legacy ExtraGalactic UV Survey (LEGUS): The HST View of Star Formation in Nearby Galaxies

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The Treasury program LEGUS (HST/GO-13364) is the first HST UV Atlas of nearby galaxies, and is aimed at the thorough investigation of star formation and its relation with galaxy environment, from the scales of individual stars to those of ~kpc clustered structures. The 154-orbits program is obtaining NUV,U,B,V,I images of 50 star-forming galaxies in the distance range 4-12 Mpc, covering the full range of morphology, star formation rate (SFR), mass, metallicity, internal structure, and interaction state found in the local Universe. The imaging survey will yield accurate recent (<50 Myr) star formation histories (SFHs) from resolved massive stars, and the extinction-corrected ages and masses of star clusters and associations. These extensive inventories of massive stars, clustered systems, and SFHs will be used to: (1) quantify how the clustering of star formation evolves both in space and in time; (2) discriminate among models of star cluster evolution; (3) investigate the effects of SFH on the UV SFR calibrations; (4) explore the impact of environment on star formation and cluster evolution across the full range of galactic and ISM properties. LEGUS observations will inform theories of star formation and galaxy

evolution, and improve the understanding of the physical underpinning of the gas-star formation relation and the nature of the clumpy star formation at high redshift. LEGUS will generate the most homogeneous high-resolution, wide-field UV dataset to date, building and expanding on the GALEX legacy. Data products that will be delivered to the community include: catalogs of massive stars and star clusters, catalogs of star cluster properties (ages, masses, extinction), and a one-stop shop for all the ancillary data available for this well-studied galaxy sample. LEGUS will provide the reference survey and the foundation for future observations with JWST and with ALMA. This abstract accompanies another one from the same project, and presents the status of the project, its structure, and the data products that will be delivered to the community; the other abstract presents the science goals of LEGUS and how these will be addressed by the HST observations.

254.09 – The Ultraviolet Sky: final catalogs of unique UV sources from GALEX, and characterization of the UV-emitting sources across the sky, and of the Milky Way extinction.

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The legacy of the Galaxy Evolution Explorer (GALEX), which imaged the sky at Ultraviolet (UV) wavelengths for about 9 years, is its unprecedented database with more than 200 million source measurements in far-UV (FUV) and near-UV (NUV), as well as wide-field imaging of extended objects. GALEX's data, the first substantial sky surveys at UV wavelengths, offer an unprecedented view of the sky and a unique opportunity for an unbiased characterization of several classes of astrophysical objects, such as hot stars, QSOs at red-shift about 1, UV-peculiar QSOs, star-forming galaxies, among others. Bianchi et al. (2013, J. Adv. Space Res. (2013), DOI: http://dx.doi.org/10.1016/j.asr.2013.07.045) have constructed final catalogs of UV sources, with homogeneous quality, eliminating duplicate measurements of the same source ('unique' source catalogs), and excluding rim artifacts and bad photometry. The catalogs are constructed improving on the recipe of Bianchi et al. 2011 (MNRAS, 411, 2770, which presented the earlier version of these catalogs) and include all data for the major surveys, AIS and MIS. Considering the fields where both FUV and NUV detectors were exposed, the catalogs contain about 71 and 16.6 million unique sources respectively. We show several maps illustrating the content of UV sources across the sky, globally, and separately for bright/faint, hot, stellar/extragalactic objects. We matched the UV-source catalogs with optical-IR data from the SDSS, GSC2, 2MASS surveys. We are also in the process of matching the catalogs with preliminary PanSTARRS1 (PS1) 3pi survey photometry which already provides twice the sky coverage of SDSS, at slightly fainter magnitude limits. The sources' SED from FUV to optical wavelengths enables classification, derivation of the object physical parameters, and ultimately also a map of the Milky Way extinction. The catalogs will be available on MAST, Vizier (where the previous version already is), and in reduced form (for agile downloading), with related tools, from the author web site " http://dolomiti.pha.jhu.edu/uvsky "

254.10 – The Dark Energy Camera and Survey

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Contributing teams: The Dark Energy Survey Collaboration

The Dark Energy Survey (DES) is a next generation optical survey aimed at understanding the accelerating expansion rate of the universe using four complementary methods: weak gravitational lensing, galaxy cluster counts, baryon acoustic oscillations, and Type Ia supernovae. To perform the survey, the DES Collaboration built the Dark Energy Camera (DECam), a 3 square degree, 570 Megapixel CCD camera that was installed at the prime focus of the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory to perform a 5000 sq-degree wide field survey and 30 sq-degree supernova survey. DES started its first observing season on August 31, 2013 and will observe for 104 1/2 nights through the end of January. This poster presentation will describe DES, the performance of the DECam instrument, and the progress and status of the DES.

254.11 – The Photometric Calibration of the Dark Energy Survey (DES): Results from the Summer 2013 Re-processing of the DES Science Verification Data

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Contributing teams: Dark Energy Survey

The Dark Energy Survey (DES) -- a five-year 5000 sq deg grizY survey of the Southern sky to probe the parameters of dark energy -- recently began operations using the new 3 sq deg DECam imager on the Blanco 4m telescope at the Cerro Tololo Interamerican Observatory. In order to achieve its science goals, the DES has tight requirements on both its relative and absolute photometric calibrations. The 5-year requirements are (1) an internal (relative) photometric calibration of 2% rms (2) an absolute color calibration of 0.5%, and (3) an absolute flux calibration of 0.5% (in i-band relative to BD+17 4708). In preparation for DES operations, the instrument+telescope underwent a period of Science Verification between November 2012 and February 2013. These Science Verification (SV) data were quickly processed to determine whether the image data were being produced with sufficient quality and efficiency to meet DES science goals. These data were also useful for initial science, and they were re-processed and re-calibrated during Summer 2013. The photometric goals for Summer 2013 re-processing of the DES SV were intentionally more relaxed than the requirements for the final 5-year survey: (1) an all-sky internal (relative) calibration goal of 3%, (2) an absolute color goal of 3%, and (3) an absolute flux goal of 3%. Here, we describe the results from the photometric calibration of the Summer 2013 re-processing of the DES SV data, the lessons learned, and plans for the future.

254.12 – White Dwarfs for Calibrating the Dark Energy Survey

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Contributing teams: DES Calibration

The Dark Energy Survey (DES) will survey some 5000 square degrees in the southern hemisphere in the grizY filter system using the newly commissioned Dark Energy Camera. In order to verify meeting photometric calibration requirements, we are obtaining the spectra of nearly 100 or more hydrogen atmosphere (DA) white dwarfs in the DES footprint. The spectra that are obtained will be extracted and used to derive synthetic spectra that can be compared with DES measurements from imaging in each of the DES grizY filters. This comparison should be able to verify and help calibrate the survey to a level better than 2% photometrically and to better than 0.5% in colors. We will discuss the observational and modeling effort required to develop a well-characterized DAs sample. This set would form the basis of a larger set of southern hemisphere survey calibration stars. These stars will be used to establish and monitor the color zero points for the DES photometric system and can be used to search for systematic errors in the color zero points over the DES footprint. These stars will also be used as some of the primary standards for the DES photometric system which will allow nightly atmospheric monitoring during DES operations.

254.13 – Photometric Calibrations of Standard Star Fields for the Dark Energy Survey

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The Dark Energy Survey (DES) is a 5000 square deg grizY imaging survey to be conducted using the new 3 square deg (2. 2-diameter) wide-field mosaic camera (DECam) on the CTIO Blanco 4-m telescope. The primary scientific goal of the DES is to constrain dark energy cosmological parameters via four complementary methods: galaxy cluster counting, weak lensing, galaxy angular correlations, and Type Ia supernovae, supported by precision photometric redshifts. Here, we describe code developed to calibrate additional standard star fields in the DES natural grizY system, and we describe our initial results using the data obtained during the DES Science Verification Phase. Some of these standard stars will be used to supplement those currently being used for nightly calibrations. Others are to be used as local tertiary standards scattered throughout the DES footprint in order to anchor the DES global relative calibrations against large-scale spatial gradients, as well as to tie the whole DES data set to an initial absolute flux scale.

254.14 – Spectroscopic Characterization of White Dwarf Candidates for Calibrating Dark Energy Survey

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Contributing teams: DES

The Dark Energy Survey (DES) is a current project in Fermilab's Cosmic Frontier. The DES is a 5000-square-degree optical/near infrared imaging survey conducted over 5 years (2013-2018) for purposes of quantifying the properties of dark energy. Synthetic photometry of pure-hydrogen-atmosphere ("DA") white dwarfs is currently the preferred technique for calibrating the absolute zeropoint calibration of large sky surveys. For absolute calibration of the DES we seek a "Golden

Sample" of 30-100 DA white dwarfs. The starting point is a photometric and spectroscopic observational campaign of ~1000 candidate white dwarfs in the DES footprint. Analysing imaging and spectroscopic data will allow us to narrow down this sample. We present results of the analysis of the observing effort. Out of 50 total white dwarf candidates imaged, 27 of them are confirmed white dwarfs.

254.15 – OzDES: 100 Nights of AAT Spectroscopy on DES Sources.

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Contributing teams: OzDES

OzDES is a 5 year, 100 night spectroscopic program on AAT using 2dF/AAOmega that commenced in September 2013. A collaboration between the Dark Energy Survey (DES) and members of the Australian astronomical community, OzDES will efficiently obtain spectra for a wide variety of DES science programs thanks to the near perfect overlap between the Dark Energy Camera and 2dF fields of view. The driver for the program is the DES Supernova Survey, as redshifts for supernova host galaxies down to r~24 can be measured through repeated integrations over the duration of the survey. In addition to supernova host galaxies and many live supernovae, OzDES will perform a study of reverberation mapping of AGN, target strong lenses, and obtain redshifts for photo-z calibration.

254.16 – First observations of supernovae from the Dark Energy Survey

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Contributing teams: Dark Energy Survey

The Dark Energy Survey supernovae survey began taking science data in September 2013 and is expected to yield ~3500 high quality SN Ia light curves by the end of its 5 year program. The newly commissioned 570 mega pixel Dark Energy Camera mounted on the CTIO Blanco 4m telescope is now regularly observing the DES SN fields. DES SN data in combination with the other DES observations of large scale structure will enable us to put increasingly accurate constraints on the expansion history of the Universe help us distinguish between competing theories of dark energy and modified gravity. We will report on the current status of the DES SN survey presenting preliminary data, survey strategy, discovery pipeline, spectroscopic target selection, data quality monitoring, comparing DES-SN performance with pre survey predictions.

254.17 – Exploring the Dependence of Galaxy Properties on Group Halo Environment in RESOLVE

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Contributing teams: The RESOLVE Team

We discuss the development of a new halo mass metric based on group dynamics for the RESOLVE survey as well as its application to understanding the dependence of galaxy properties on environment. Methods and parameters for group finding and calculating dynamical mass are optimized on a mock catalog with similar redshift range to RESOLVE. We also develop additional metrics of the evolutionary state of the group. These methods are applied to a sample of galaxies in the B-semester footprint of the RESOLVE survey, which overlaps with SDSS Stripe 82, as well as the ECO catalog, a larger volume-limited survey that encloses the A-semester footprint of RESOLVE. Using both dynamical halo mass and halo evolutionary state to quantify environment, we study its influence on galaxy properties such as color, gas content, and star formation history. We acknowledge REU funding support to Vanderbilt under NSF grant PHY-1263045 and to the RESOLVE survey at UNC Chapel Hill under AST-0955368.

254.18 – Toward Detection of Low-Metallicity AGN in the RESOLVE Survey

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Contributing teams: RESOLVE

AGN are frequently identified using the BPT method in which quasars,Seyferts, and LINERS are clearly separated from star forming galaxies. However, recent modeling suggests that low-metallicity AGN do not separate from star-forming galaxies in

the BPT diagram, potentially resulting in unidentified AGN. We present initial results of our efforts to identify low-metallicity AGN in the RESOLVE survey using emission-line profile fitting to search for extended line wings indicative of possible AGN activity. The RESOLVE survey is an excellent test bed as a low-redshift, volume-limited survey dominated by dwarf galaxies. Our ultimate goal is to measure the relative frequency of heretofore undetected AGN and estimate their impact on star formation feedback, chemical evolution of galaxies, and the re-ionization of the universe at earlier times. This project was supported by NSF REU funding for the UNC Chapel Hill CAP REU program (OCI-1156614), the RESOLVE survey (AST-0955368), and the NOAO/KPNO REU Program (AST-0754223 and AST-0132798, respectively cofunded by the Department of Defense ASSURE program through Scientific Program Order No. 13 and the Association of Universities for Research in Astronomy).

254.19 – RESOLVE'd AGN: Refining Active Galactic Nuclei Classification Techniques

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Contributing teams: the RESOLVE Team

We use multi-wavelength methods to select a sample of nearby Active Galactic Nuclei (AGN) for further environmental study. Data from the RESOLVE survey, a volume-limited census within >50,000 cubic Mpc (Kannappan et al. 2013), is merged with Wide-Field Infrared Survey Explorer (WISE) data and the Sloan Digital Sky Survey (SDSS) DR7 release to identify AGN in the nearby ($z \sim 0.02$) cosmic web. The volume-limited nature of RESOLVE is of particular interest as it allows for close examination of AGN environments and fueling mechanisms. We identified a group of objects that are classified as star forming galaxies with the Baldwin-Phillips-Terlevich diagnostic diagram, but have mid-IR colors that suggest they may be AGN. The ambiguous nature of these objects makes them interesting targets for further investigation. We confirm that one such galaxy in the RESOLVE survey shows high-excitation metal emission line profiles. Behmard was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program (AST-1262829), as well as the UNC Chapel Hill CAP REU program (OCI-1156614), both of which are funded by the National Science Foundation. This project was also supported through the RESOLVE survey (AST-0955368) and makes use of data products from the WISE, which is a joint project of the UCLA, and the JPL/CalTech, funded by NASA.

254.20 – RESOLVE Survey Early Results: The Environment Driven shape of the Baryonic Mass Function

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Contributing teams: and the RESOLVE team

We present the stellar and baryonic (stars plus cold gas) mass functions (SMF and BMF) and their environment dependence for two volume-limited galaxy samples in the nearby universe. The REsolved Spectroscopy Of a Local VolumE (RESOLVE) survey encompasses a > 50,000 cubic Mpc volume including a highly complete 14,000 cubic Mpc volume within Stripe 82, allowing investigation of mass functions into the gas-rich dwarf regime in the baryonic mass range 10^9 and 10^{10} Msun. The Environmental COntext (ECO) catalog covers a much larger volume for improved statistics but goes less deep. To construct the SMF and BMF, we implement a Monte Carlo technique that samples from the full likelihood distributions of both the stellar masses from SED fitting and the gas masses from either HI measurements or color-based estimates. The SMFs for our samples exhibit a plateau below Mstar $\sim 10^{10}$ Msun similar to structure seen in previous work. The BMF fills in this feature and rises as an approximately straight power law for galaxies with masses $< 10^{10}$ Msun, reflecting the importance of gas-rich and gas-dominated galaxies in the low-mass galaxy population. Investigation of the BMF in different halo mass regimes, however, reveals complex structure including an intriguing dip in the BMF at Mbary $\sim 10^{10}$ Msun in massive group halos and variable slopes at the low mass end. We tie these features to the central and satellite galaxy populations and discuss them in the context of galaxy evolution. Finally, we examine how halo mass dependence combined with cosmic variance influences BMF measurements. This project was supported by NSF funding for the RESOLVE survey (AST-0955368).

254.21 – Metallicities of Galaxies in the Dwarf-Dominated RESOLVE Survey

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Contributing teams: RESOLVE team

We present preliminary gas-phase metallicity measurements of emission line galaxies in the RESOLVE Survey. RESOLVE is a volume limited census of more than 1500 nearby galaxies (cz = 4500-7000 km/s) with a survey mass limit of around 10^9 solar masses. This mass limit probes the oft overlooked population of dwarf galaxies. Furthermore the greater than 50,000 cubic Mpc volume of RESOLVE covers a wide range of environments. These features combine to make RESOLVE the ideal data set for studying the environment-dependent galaxy mass-metallicity relationship, particularly at the low mass end. We explore the scatter in this relationship at fixed mass to assess secondary physical drivers of metallicity and to search for tidal dwarf galaxies. RESOLVE spectroscopy also permits the measurement of metallicity gradients in single or multiple long slit cuts across individual galaxies. We present initial results using these gradients to illuminate the history and origins of gas accreting onto dwarf galaxies. This project was supported by NSF funding for the RESOLVE survey (AST-0955368).

254.22 – Determining the Intrinsic Shapes of Galaxies in the RESOLVE and ECO Surveys

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Contributing teams: the RESOLVE team

We present an algorithm for determining the intrinsic shapes (edge-on axial ratios) of galaxies from the distribution of observed shapes. Galaxies are modeled as oblate ellipsoids, and the effects of nonaxisymmetry in the galaxies, seeing, and errors in measuring apparent axis ratios are included. A model grid with up to three intrinsic shapes and variable fractions of galaxies with each intrinsic shape is generated, and the models in the grid are compared to the data. We analyze likelihood distributions to identify the intrinsic shapes and the fraction of galaxies with each intrinsic shape. We test this algorithm by application to a massive early-type sample selected from the volume-limited Environmental COntext (ECO) catalog. The data are consistent with intrinsic axial ratios of 0.33 (42.5% of galaxies), 0.50 (27.9% of galaxies), and 0.72 (29.5% of galaxies). More specifically, galaxies with higher stellar masses, higher halo masses, and higher densities are found to have rounder intrinsic shapes, as expected. We describe work in progress to apply our modeling algorithm to dwarf galaxies in the volume-limited RESOLVE survey, which provides an exceptionally complete view of the low-mass galaxy population across multiple z=0 environments. This research was funded by NSF AST-0955368 and CAP REU OCI-1156614.

254.23 – The Fueling Diagram and the RESOLVE Survey: Assessing External Drivers of Galaxy Gas Content

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Contributing teams: the RESOLVE team

We assess how external factors such as local interactions and fresh gas accretion influence the global interstellar medium of galaxies. We first present recently published work that uses a broad sample of field galaxies, spanning early-to-late type morphologies and dwarf-to-giant stellar masses, to reveal that galaxies occupy several loci in a "fueling diagram". This diagram plots molecular-to-atomic (H_2/HI) gas ratio versus mass-corrected blue-centeredness, a metric tracing the degree to which galaxies have bluer centers (higher recent central star formation) than the average galaxy at their stellar mass. We argue for a systematic link between local galaxy interactions and molecular gas inflow/replenishment, with most galaxies showing increased H_2/HI in tandem with enhanced blue-centeredness. Intriguingly, a distinct population of blue-sequence E/S0 galaxies (apparently gas-rich low-mass merger remnants currently in late- or post-starburst states) defines a separate loop in the fueling diagram such that the burst first depletes the H_2 while the galaxy center keeps getting bluer, then exhausts the H_2 so that the central burst reddens and the galaxy evolves back toward the spiral locus. During the H_2 depleted phase, total gas-to-stellar mass ratios actually rise, suggesting fresh gas accretion and disk regrowth. We build on this work by examining the global HI content of galaxies within the volume-limited RESOLVE (REsolved Spectroscopy Of a Local VolumE) survey to assess signatures of enhanced cosmic accretion as a function of mass and environment regimes. This project was supported by NSF funding for the RESOLVE survey (AST-0955368) and the GBT Student Observing Support program.

254.24 – RESOLVE: Constructing a Baryonic Tully-Fisher Relation Reference Sample across Environments

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Contributing teams: RESOLVE Team

The RESOLVE (REsolved Spectroscopy Of a Local VolumE) survey is assembling a uniquely powerful data set for studies of the baryonic Tully-Fisher relation (BTFR) as a function of environment at z = 0. We review the current inventory of HI 21cm data from GBT, Arecibo, and ALFALFA in addition to SOAR and SALT rotation curves. From the available data, we construct the BTFR down to $M_{bary} \sim 10^9$ M_{Sun}. We search for preliminary indications of environment dependence using criteria such as group halo mass, smoothed environmental density, and nearest neighbor distance. We also compare our results to high-z BTFR data. We acknowledge funding for the RESOLVE survey (NSF AST-0955368)

254.25 – RESOLVE and ECO: Galaxy Refueling Transitions in Environmental Context

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Recent work has demonstrated that galaxies undergo two key transitions in refueling. Below the threshold mass (baryonic mass Mbary~10^10 Msun or V~125 km/s), gas-dominated late-type galaxies and blue, disk-building E/S0 galaxies become abundant, reflecting an increase in accretion-dominated states. Between the threshold mass and the bimodality mass (Mbary~10^10.6 Msun or V~200 km/s), "normal" intermediate gas content bulged spiral galaxies like our Milky Way become most common, reflecting reduced accretion, while at higher masses quenched E/S0s start to dominate. Notwithstanding these results, the high scatter in gas and long-term star formation trends as a function of galaxy mass implies that mass is a secondary driver of refueling, motivating an inquiry into the role of environment. We present two surveys designed to meet this need: the REsolved Spectroscopy Of a Local VolumE (RESOLVE) survey and the Environmental COntext (ECO) catalog encompassing it. Initially selected from the SDSS, both surveys offer enhanced redshift completeness and custom reprocessed NUV+ugriz+JHK photometry. RESOLVE comprises >1500 galaxies down to baryonic mass ~10^9 Msun, for which we are building a comprehensive census of stellar, gas, and dynamical mass as well as star formation and environment data. The RESOLVE database includes spatially resolved optical spectroscopy from SOAR, SALT, and Gemini in both high-resolution kinematic mode and low-resolution stellar population mode, as well as deep 21cm observations from the GBT and Arecibo aimed at detecting HI down to 5%-10% of each galaxy's stellar mass. ECO has nearly ten times larger volume than RESOLVE, with matched environment and stellar mass metrics as well as shallower HI data inherited from the 21cm ALFALFA survey, but only SDSS spectroscopy. Here we use the first wave of gas, star formation, and environment data for RESOLVE and ECO to explore the halo mass dependence of refueling, finding that both gas-dominated galaxies and blue, disk-building E/S0s are predominantly centrals in halos with mass below ~10^11.5 Msun. We show that below this scale galaxies routinely double their stellar masses on ~Gyr timescales, likely pointing to a shift in cosmic accretion physics.

254.26 – Compact Core Galaxies in the RESOLVE Survey

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Contributing teams: The RESOLVE Team

We identify a population of galaxies with half-light radii <1kpc in the highly complete RESOLVE (REsolved Spectroscopy Of a Local VolumE) survey, representing a few percent of its ~1500 galaxies. These "compact core galaxies" (CCGs) include both compact ellipticals (cEs) and CCGs with envelopes of gas and stars. They occupy both isolated and non-isolated environments, spanning a variety of large scale structures in RESOLVE, including clusters, walls, and filaments. We deconvolve the radii of these galaxies with their seeing profiles, as CCGs are strongly affected by seeing at RESOLVE distances. We compare their radii and star formation histories with those of globular clusters, ultra compact dwarfs (UCDs), and cEs in the ~300 object AIMSS (Archive of Intermediate Mass Stellar Systems) catalog, making use of cross-matched GALEX NUV data for both data sets. We also present Gemini observations of velocity dispersions of the CCGs for comparison with RESOLVE and AIMSS kinematic data. By examining all of these properties, we seek to discriminate between formation scenarios for CCGs, such as tidal stripping (a likely scenario if they represent the high-mass end of the UCD population) or dissipative major mergers (a likely scenario if they represent the low-mass end of the massive spheroid population). We also use properties of AIMSS sample objects such as color and environment to guide the development of new algorithms for

finding potentially overlooked cEs/CCGs in RESOLVE. Increasing the completeness of our sample of compact galaxies will strengthen its statistical power for analysis of their formation scenarios as a function of environment. This work is supported by the National Science Foundation under AST-0955368, and by the grant HST-AR-12147.01-A .

254.27 – Kinematic Anomalies in the RESOLVE Survey and the Gas-Star Formation Connection

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Contributing teams: the RESOLVE Team

We compare optical kinematics with HI fluxes and linewidths as well as measures of star formation for galaxies in the RESOLVE (REsolved Spectroscopy Of a Local VolumE) survey. We identify and analyze discrepancies between the HI and ionized gas dynamics. In addition, we quantify anomalous kinematic behavior of the ionized gas by measuring rotation curve asymmetries, turbulence, and central concentration of the emission. We then interpret these properties in the context of environmental factors such as interactions and accretion, making use of additional data probing neutral gas content and recent star formation averaged over different timescales. Separately, we present results from a study of star formation and molecular gas at somewhat higher redshift. We construct a Kennicutt-Schmidt relation in Lyman break galaxy analogs at z~0.2 to assess the applicability of the relation in Lyman break galaxies at z~3. The authors thank the National Science Foundation for funding the RESOLVE research under CAREER award 0955368 as well as funding the Lyman break galaxy analogs research under grant AST-0955810.

254.28 – A Precision Multi-Band Two-Epoch Photometric Catalog of 45 Million Sources from Combination of the USNO-B and Sloan Digital Sky Survey Catalogs

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A key science driver for the next generation of wide-field optical and radio surveys is the exploration of the time variable sky. These surveys will have unprecedented sensitivity and areal coverage, but will be limited in their ability to detect variability on time scales longer than the lifetime of the surveys. We present a new precision, multi-epoch photometric catalog that spans 60 years by combining the USNO-B and SDSS Data Release 9 catalogs. We recalibrate the photometry of the original USNO-B catalog and create a catalog with two epochs of photometry in up to five different bands for 44,608,810 optical point sources that lie in the DR9 footprint of the northern sky. The recalibrated objects span a magnitude range 14 < m < 20 and are accurate to ? 0.1 mag. We minimize the presence of spurious objects and those with inaccurate magnitudes by identifying and removing several sources of systematic errors in the two originating catalogs, with a focus on spurious objects that exhibit large apparent magnitude variations. After accounting for these effects, we find ?260,000 stars and quasars that show significant (?4?) changes in brightness between the USNO-B and SDSS DR9 epochs. We discuss the historical value of the catalog and its application to the study of long time-scale, large amplitude variable stars and quasars.

254.29 – A Long Term High-Cadence Nova Survey

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We have initiated a nova survey that uses a previously unstudied long term high cadence archive data set covering about 1/3 of the sky to 1) improve on the number and recurrence frequency of recurrent novae (RNe), and 2) permit an investigation of the puzzling and diverse set of features in classical novae (CNe) and RNe light curves. RNe are of great astrophysical interest because they have long been considered to be the prime candidates for progenitors of Type Ia supernovae. However, the recurrence time scale is not well known, but is an essential parameter determining whether any RNe become Type Ia supernovae. Novae exhibit a wide variety of light curves with features like pre-eruption rises and dips, flat-tops at peak, and flares superimposed on decline, for example. These features are poorly understood. The answers require more and better light curves. The data set our team is using to address RNe occurrence and light curves was taken in the 1950's over a nearly 9 year period with two Baker Super-Schmidt telescopes 80 km apart in New Mexico, resulting in 42,000 photographic images. Each telescope had a 52 degree field of view. Images to a limiting stellar magnitude of 13 were taken at a rate of 2-3 per hour sampling a total of one-third of the entire sky. A similar data set does not exist anywhere else, nor is one planned with such high cadence and field of view. We are digitizing the films and through a data pipeline plan to identify candidate RNe and new CNe enhancing the number of known RNe and creating light curves leading up to and following novae

eruptions. We will describe the digitizing process and data pipeline, and initial results from the first 1,600 films that we have surveyed.

254.30 – Surveys, Fields, and Collections in the Astronomical Photographic Data Archive at PARI

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A diverse set of photometric, astrometric, spectral and surface brightness data exist on more than 100 years of photographic glass plates. About 20 percent of the plates in North America are located in the Astronomical Photographic Data Archive (APDA) at the Pisgah Astronomical Research Institute (PARI). APDA was established in November 2007 and is dedicated to the task of collecting, restoring, preserving and storing astronomical photographic data and PARI continues to accept collections. APDA is also tasked with scanning each image and establishing a database of images that can be accessed via the Internet by the global community of scientists, researchers and students. APDA is a new type of astronomical observatory – one that harnesses analog data of the night sky taken for more than a century and making that data available in a digital format. APDA currently has 50 collections with more than 250,000 plates taken for QSO identification, parallax measurements, spectral classification and monitoring, Magellanic Cloud studies, H-alpha emission star surveys, novae evolution, and astrometry of asteroids, outer planet satellites and Pluto. Some examples of collections include the complete set of the Henize H-alpha Southern Survey plates taken between 1949 and 1952 (Henize 1954, AJ, 59, 325), the Case Western Objective Prism All Sky Survey from 1958-1976 (e.g. Pesch, Sanduleak, and Stephenson 1996, ApJS, 103, 513), and QSO Survey from 1980 to 1991 (e.g. Pesch and Stephenson 1983, ApJS, 51, 171). We feature the contents of the APDA collections to provide the opportunity to the astronomical community to advance new and established areas of study.

254.31 – Mapping Nearby Galaxies at APO: The MaNGA IFU Galaxy Survey

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Contributing teams: MaNGA Team

MaNGA is a new survey that will begin in August 2014 as part of SDSS-IV with the aim of obtaining integral-field spectroscopy for an unprecedented sample of 10,000 nearby galaxies. MaNGA's key goals are to understand the "life cycle" of present day galaxies from imprinted clues of their birth and assembly, through their ongoing growth via star formation and merging, to their death from quenching at late times. To achieve these goals, MaNGA will channel the impressive capabilities of the SDSS-III BOSS spectrographs in a fundamentally new direction by marshaling the unique power of 2D spectroscopy. MaNGA will deploy 17 pluggable Integral Field Units (IFUs) made by grouping fibers into hexagonal bundles ranging from 19 to 127 fibers each. The spectra obtained by MaNGA will cover the wavelength range 3600-10,000 Angstroms (with a velocity resolution of ~ 60 km/s) and will characterize the internal composition and the dynamical state of a sample of 10,000 galaxies with stellar masses greater than 10^9 Msun and an average redshift of z ~ 0.03. Such IFU observations enable a leap forward because they provide an added dimension to the information available for each galaxy. MaNGA will provide two-dimensional maps of stellar velocity and velocity dispersion, mean stellar age and star formation history, stellar metallicity, element abundance ratio, stellar mass surface density, ionized gas velocity, ionized gas metallicity, star formation rate, and dust extinction for a statistically powerful sample. This legacy dataset will address urgent questions in our understanding of galaxy formation, including 1) The formation history of galaxy subcomponents, including the disk, bulge, and dark matter halo, 2) The nature of present-day galaxy growth via merging and gas accretion, and 3) The processes responsible for terminating star formation in galaxies. Finally, MaNGA will also play a vital role in the coming era of advanced IFU instrumentation, serving as the low-z anchor for interpreting IFU observations of galaxies at z = 2-4.

254.32 – URAT - year 2

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The USNO Robotic Astrometric Telescope (URAT) is now in the second year of observing. Survey observing began in April 2012 at the Naval Observatory Flagstaff Station (NOFS). URAT took over 33000 exposures of the northern sky with multiple overlaps, 28 sq.degrees with a single exposure at 0.9"/mm resolution. The quality control pipeline is now fully implemented. In normal survey mode URAT covers stars in the R = 18.0 to 10.5 magnitude range. Utilizing an objective grating and the Clocked Anti Blooming (CAB) feature of the 4 CCD chips the bright limit is at about 3rd magnitude. Exposures taken on the East and West side of the pier allow to calibrate systematic errors. URAT mean positions are predicted to be on the 5 to 10 mas level after 3 years of operations. URAT will also provide proper motions and parallaxes for nearby stars, independent of

any selection criteria. A first catalog is expected to be released in 2014.

254.33 – CRTS2: A Continuation of the Catalina Real-Time Transient Survey

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Contributing teams: CRTS Team

Catalina Real-Time Transient Survey (CRTS; http://crts.caltech.edu) is systematically exploring and characterizing the faint, variable sky. It uses data streams generated by the Catalina Sky Survey, which searches for near-Earth asteroids, and uses the same data to search for variable objects and transient events. The CRTS survey has been in operation since 2008, with the archival data going back to 2005. A continuation of the survey (CRTS2) has now been funded by the NSF, and we are forming an international consortium of research groups and institutions for an expanded and extended coverage and a broader scientific exploitation. We have a complete open data policy: all discovered transient events are published in real time with no proprietary delay period, and all data are made public, in order to better serve the entire community, and maximize the scientific returns. Briefly, the survey covers the total area of ~33,000 deg2, down to ~19-21 mag per exposure, with time baselines from 10 min to 8 years, and growing; there are now typically ~ 300 - 400 exposures per pointing, and coadded images reach deeper than ~ 23 mag. The area coverage rate will increase substantially as new cameras are being deployed, and possible new data streams opened. The CRTS survey has so far detected over 8,000 unique, high-amplitude transients, including over 2,000 supernovae (for 4 or 5 years in a row we published more supernovae than any other survey), well over 1,000 CVs (the great majority of them previously uncatalogued), over 2,500 of blazars / OVV AGN, and a broad variety of other types of objects. We have about 500 million light curves, which are being updated continuously. This is an unprecedented data set for the exploration of the time domain, in terms of the area, depth, and temporal coverage. Numerous scientific projects have been enabled by this data stream, including: discoveries of ultraluminous and otherwise peculiar SNe; unusual CVs and dwarf novae; variability-based IDs of Fermi gamma-ray sources; mapping of the structure in the Galactic halo using RR Lyrae; variability-based discovery of AGN; etc. We have a major effort on the automated classification of transient and variable sources.

254.34 – The Strong Lensing Time Delay Challenge (2014)

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Time delays between multiple images in strong lensing systems are a powerful probe of cosmology. At the moment the application of this technique is limited by the number of lensed quasars with measured time delays. However, the number of such systems is expected to increase dramatically in the next few years. Hundred such systems are expected within this decade, while the Large Synoptic Survey Telescope (LSST) is expected to deliver of order 1000 time delays in the 2020 decade. In order to exploit this bounty of lenses we needed to make sure the time delay determination algorithms have sufficiently high precision and accuracy. As a first step to test current algorithms and identify potential areas for improvement we have started a "Time Delay Challenge" (TDC). An "evil" team has created realistic simulated light curves, to be analyzed blindly by "good" teams. The challenge is open to all interested parties. The initial challenge consists of two steps (TDC0 and TDC1). TDC0 consists of a small number of datasets to be used as a training template. The non-mandatory deadline is December 1 2013. The "good" teams that complete TDC0 will be given access to TDC1. TDC1 consists of thousands of lightcurves, a number sufficient to test precision and accuracy at the subpercent level, necessary for time-delay cosmography. The deadline for responding to TDC1 is July 1 2014. Submissions will be analyzed and compared in terms of predefined metrics to establish the goodness-of-fit, efficiency, precision and accuracy of current algorithms. This poster describes the challenge in detail and gives instructions for participation.

254.35 – The Swift/BAT hard X-ray transient monitor: Seven years and 246 sources, still going strong!

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The Swift/BAT hard X-ray transient monitor has been operating continuously since October 2006 as a near real-time full-sky monitor in the 15-50 keV energy range with a detection sensitivity of ~5 mCrab; and the first major monitor catalog paper has just been published. Here we review the many important findings of the transient monitor, with particular emphasis on the 18 previously unknown galactic and extra-galactic sources that were first uncovered by the monitor. This list includes six neutron stars, five black hole candidates and a tidal disruption flare event. We will also summarize and classify the 246 sources previously known, or discovered elsewhere, which have been detected in the transient monitor either with persistent emission (146 sources) or in outburst (100 sources). We will also briefly discuss the recent improvements to the monitor and plans for the future.

254.36 – Optical Photometry of the Local Volume Legacy (LVL) Survey

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Contributing teams: LVL Team

We present new optical (UBVR) imaging of 258 nearby (D < 11 Mpc) galaxies in the Local Volume Legacy (LVL) survey. The volume limited sample is dominated by dwarf galaxies, however, the sample as a whole probes many global galaxy environments. This photometry completes the panchromatic data set which spans a wide wavelength range (1500 Å - 160 µm). This study focuses on GALEX (FUV & NUV), optical (UBVR), 2MASS (JHK), and Spitzer (3.6 µm, 4.5 µm, 5 um, 8 µm, & 24 µm) data. Photometry was performed with three separate apertures (defined from the FUV, 3.6 µm, and optical) to allow direct photometric comparisons between galaxies with consistent apertures. The wide wavelength coverage with uniform apertures across many environments will facilitate studying the effect of secular galaxy evolution and environment on galaxy-wide properties. Furthermore, the proximity of these galaxies will yield a wealth information on sub-kpc scales since individual star-forming regions can be identified and studied with the same wide wavelength coverage. We present the basic optical properties and SEDs of these galaxies and their relationships to the full panchromatic data set to evince underlying physical processes.

254.37 – The Advanced Spectral Library (ASTRAL) Project

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Contributing teams: The ASTRAL I & II Science Teams

The Advanced Spectral Library (ASTRAL) is an HST Treasury Program whose aim is to secure definitive ultraviolet (115-310 nm) spectra of representative bright stars utilizing the venerable -- yet still state-of-the-art -- Space Telescope Imaging Spectrograph (STIS). The initial Cycle 18 installment of the program (146 orbits in 2010-2011) focused on late-type (``cool'') stars, acquiring high-S/N, high spectral resolution measurements of eight pivotal targets, including iconic objects like Betelgeuse and Procyon. The latest episode, in current Cycle 21 (230 orbits in 2013-2014), is designed to record very high-S/N (>100) STIS echellegrams, at the highest resolution feasible (R~30,000-100,000), of 21 representative bright early-type (``hot'') stars, including equally iconic objects like Vega, Sirius, Regulus, and Zeta Puppis. The targets span a broad range of spectral types between early-O and early-A, encompassing main sequence and evolved stars, fast and slow rotators, as well as chemically peculiar and magnetic objects. These high-quality STIS UV spectra will be publicly available immediately after observation from the HST archive; and, in post-processed and merged form, at the project website: http://casa.colorado.edu/~ayres/ASTRAL/. The UV "atlases" produced by the ASTRAL Program will enable investigations of a broad range of astrophysical problems -- stellar, interstellar, and beyond -- for many years to come. Supported by Guest Observer grants from STScI.

254.38 – Spatial Variation of Deep Galaxy Number Counts: A Method Of Constraining Extinction With LSST

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The variation across the sky of galaxy number counts is strongly affected by extinction and large-scale structure. How well we can correct for extinction will likely determine our ability to characterize the clustering of galaxies and their evolution. With a new generation of multicolor imaging surveys, such as the Large Synoptic Survey Telescope (LSST), we study how well we might be able to constrain extinction through deep galaxy number counts. We calculate the two-point angular correlation function w(?) from Limber's approximation and use it to determine the amount of apparent clustering that the LSST will observe in each photometric band. The clustering strength, which is a function of survey depth and resolution, is translated into a corresponding scatter in apparent magnitude measurements. We combine the expected scatter from clustering with an estimate for scatter due to weak gravitational lensing and photometric errors to place a lower bound on the accuracy of extinction values. In addition, we examine whether cross correlating galaxy distributions at different depths is useful at improving our extinction measurements.

254.39 – Impact of LSST filter properties on simulated supernovae samples

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Contributing teams: LSST Collaboration, LSST-DESC, LSST Supernova

Using simulated supernovae samples, we investigate the impact of transmission properties of the optical filters for the Large Synoptic Survey Telescope (LSST). The LSST has a choice of at least four vendors, capable of building the u-g-r-i-z-y curved filters, spanning 75 centimeters in diameter and each with a different thickness to maintain optical quality for each bandpass. Factors such as out-of-band leakage, ripple amplitude, flat-top transmission level, and taper, which are part of the specification of the filter, play a role in achieving high quality data collected for the LSST science. The supernova photometric simulations were performed for the filter characteristics achieved by each vendor using the full 10-year LSST program using the Deep Drilling Fields. The simulated light curves were fit with the SALT2 Type Ia model allowing the photometric redshift to vary. The light curve fits were performed with and without host galaxy photo-z priors. The precision of the photometric redshifts were measured for each vendor, and we present which aspects of the filters were most important in photo-z precision. In addition, we study the purity of the Type Ia supernova sample, hence how much contamination from core collapse supernovae we expect for filters from each vendor. We compare the results of these filter transmission studies with others conducted within LSST.

254.40 – Sloan Digital Sky Survey Infrastructure Preparations at Las Campanas Observatory

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Contributing teams: SDSS-IV, APOGEE-1/2

The Sloan Digital Sky Survey, conducted on the Sloan Foundation Telescope at Apache Point Observatory for the last 15 years, is embarking on a dual hemisphere survey. This next iteration of the survey, termed SDSS-IV, will conduct a portion of the galactic evolution experiment APOGEE in Chile on the du Pont Telescope at the Las Campanas Observatory; critical portions of the Galaxy are best or only accessible in southern skies. The infrastructure for the southern survey will be derived from the mature and productive systems at APO, while the concept of operations will significantly depart from the established SDSS model. Presented herein are the elements that comprise the LCO infrastructure and the rationale for the envisioned survey operations.

254.41 – Massive Spectroscopic Followup of Transients from the Multi-Epoch Nearby Cluster Survey

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The Multi-Epoch Nearby Cluster Survey (MENeaCS) monitored 60 low redshift (0.05<z<0.15), X-ray luminous galaxy clusters for two years, with a primary science goal of measuring the cluster type Ia supernova rate, and constraining the type Ia delay time distribution. A fraction of our spectroscopic follow-up of supernova candidates was done with Hectospec, a 300-fiber, ~1deg^2 spectrograph on the MMT. We utilized spare fibers, typically ~65 per visit, to classify all of our transient sources, without observational preconditions or selection criteria. This total set of 470 spectra allow for an unbiased look at the transient sky, and we will present their basic demographics. We will also discuss the implications for spectroscopic follow-up in the era of the Large Synoptic Survey Telescope.

254.42 – Infrared Study of Galaxies in the Zone of Avoidance

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The Zone of Avoidance (ZoA) is a region of the sky in which extinction at optical wavelengths is very high due to the gas and dust of the Milky Way (e.g. Kraan-Korteweg et al. 2000, A&ARv, 10, 211). This region is bounded by low latitudes in the galactic coordinate system. A visual inspection of optical or infrared images and HI surveys are still the best ways to identify new galaxy candidates in the ZoA. Many all sky surveys at long wavelengths have been completed and are available through public databases (e.g. WISE, SDSS) allowing their use in other research projects. In this poster we present the results of an infrared study of a small region in the anti-center ZoA taking advantage of IRSA/IPAC archive data. We searched for infrared emission for a sample of 86 galaxies studied in HI by Pantoja et al. (1994, AJ, 108, 92). The WISE space telescope archived data at 3.4, 4.6, 12µm and 22µm was used. Composed images using the 3.4, 4.6 and 12µm bands are presented together with single images of the 22 µm band. Most of the galaxies detected in HI by Pantoja et al. (1994) are bright at 12 and 22µm, indicating the presence of hot dust. This is expected from galaxies with a lot of gas, dust and star formation. On the other hand, most of the 56 galaxies without HI emission are brighter at 3.4 and 4.6µm and had no emission in the 22µm band. These characteristics may be linked to small amount of gas and dust. This research has made use of the NASA/IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. We gratefully acknowledge the support from the Fundación Comunitaria de Puerto Rico for this project.

254.43 – The LCOGT Science Collaboration

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Las Cumbres Observatory Global Telescope (LCOGT) has deployed a global network of 1-m and 2m optical telescopes, optimized for work in time-domain astronomy. Since our scientific staff is rather small, and since network operation necessarily involves close collaborations with other astronomical institutions, we aim to extend the scientific depth and scope of the Observatory by creating a formal Science Collaboration. This poster explains the structure and membership of the Collaboration, with emphasis on the notion of Key Projects that we intend as vehicles to perform scientific programs for which LCOGT's facilities are uniquely suited, and which will have the greatest scientific impact. The general subjects of these projects are already defined (Supernovae, Extrasolar Planets, Solar System, AGN, and Stellar Astrophysics). A Collaboration-wide proposal process to be carried out in early 2014 will determine which problems within these categories will be addressed in the first round of Key Projects.

254.44 – SMASH: The Survey of the MAgellanic Stellar History

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Serena, Chile. 9. Columbia U., New York, NY, United States. 10. U. Virginia, Charlottesville, VA, United States. 11. Instituto de Astrofísica de Canarias, Tenerife, Spain. 12. U. Colorado, Boulder, CO, United States. 13. STScI, Baltimore, MD, United States. 14. Strasbourg Observatory, Strasbourg, France. 15. MPIA, Heidelberg, Germany. 16. U. Groningen, Groningen, Netherlands. 17. Arizona State U., Tempe, AZ, United States. 18. U. Hertfordshire, Hertfordshire, United Kingdom. 19. Kapteyn Astronomical Institute , Groningen, Netherlands.

We report on early pilot program results and progress made in the Survey of the Magellanic Stellar History (SMASH). SMASH is an NOAO community survey that is using the Dark Energy Camera (DECam) to map a 2400 deg^2 area (at 20% filling factor, or 480 deg^2 total) of the Magellanic Clouds and their periphery in ugriz. With depths of griz~24 and u~23, SMASH will: (1) map the stellar periphery of the Clouds with old main sequence turnoff stars to a surface brightness limit of 35mag/arcsec^2,(2) identify the stellar component of the Magellanic Stream and Leading Arm for the first time, if they exist, and (3) derive spatially-resolved star formation histories covering all ages out to large radius from the Cloud centers. Combined with the Dark Energy Survey, SMASH will explore a vast area for hidden Magellanic Cloud populations, providing new insight into the complex and dramatic history of these two iconic dwarf galaxies.

254.45 – Photometric Analysis of Clusters in the Vista Variables in the Via Lactea (VVV) Survey

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The study of open clusters provides insight into the evolution of stars. We present color-color and color-magnitude diagrams of stars detected in three J, H, and Ks-band images from the VVV survey. The images are located on the Galactic longitude edge of the VVV survey, corresponding to galactic l=295 and b=-0.65, and covering 1.1x1.5 square degrees. Using the results from both aperture and point spread function (PSF) photometry, the stellar populations and clusters present in these diagrams are discussed. We also outline the various advantages and disadvantages of aperture and PSF photometry and possible sources of error in our methods.

254.46 – First results from the Chandra COSMOS Legacy survey

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Contributing teams: and the Chandra COSMOS Legacy Team

The equatorial 2 deg2 COSMOS area is the only large field for which a complete, deep, pan-chromatic data set exists, from an outstanding survey effort, and that all large telescopes can observe. During 2013, this pioneering and ambitious COSMOS survey had a major extension, pushing its frontiers via the newly approved Chandra COSMOS Legacy Survey, the second largest Chandra proposal ever approved, plus new deep Spitzer, JVLA and NuSTAR surveys all aimed to study the formation of the structures in the high redshift Universe and the role of active super massive black holes. The Chandra COSMOS-Legacy survey uniformly covers the 1.7 deg2 COSMOS/HST field with 2.8 Ms of Chandra ACIS-I imaging at ~160 ksec depth. This project expands the deep C-COSMOS area by a factor of ~3 at ~3e-16 (1.45 vs 0.44 deg2). The survey consists of 56x50 ks tiles covering a total area of 2.2 deg2 yelding a sample of ~4000 X-ray sources. In this poster we present the first results on the survey and we concentrate on the high redshift z>3 sample.

254.47 – The NEWFIRM HETDEX Survey - Studying Galaxy Growth with 400,000 Galaxies at 2 < z < 3.5

Matthew L. Stevans[1], Steven L. Finkelstein[1], Karl Gebhardt[1], Shardha Jogee[1], Casey J. Papovich[2], Robin Ciardullo[3], Caryl Gronwall[3], Viviana Acquaviva[4], Tim Weinzirl[1]
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Contributing teams: HETDEX

We present the NEWFIRM HETDEX survey - a K-band survey with NEWFIRM on the KPNO 4m Mayall telescope of a 28 deg^2 region of the Hobby Eberly Telescope Dark Energy Experiment (HETDEX) equatorial field. Here we provide the survey plan, as well as results from the first year (out of four) of our survey. When combined with deep ugriz images from the Dark Energy Camera, deep 3.6 and 4.5 micron images from Spitzer/IRAC, deep far-IR imaging at 250, 350, and 500 microns from HERSCHEL-SPIRE, and R ~ 800 integral-field spectroscopy from the Hobby-Eberly Telescope's VIRUS spectrographs (filling factor 1:1), our observations will allow extinction-corrected star-formation rates (SFRs) to be obtained for ~400,000

galaxies at 2 < z < 3.5. Our survey covers a co-moving volume of 0.5 Gpc^3 and is sensitive to SFRs down to 10 Msol/yr, covering a 10-100 times larger volume and going three times deeper than previous surveys. Our very large volume will allow us to explore galaxy growth as a function of stellar mass, halo mass, and local environment, in addition to providing K-band legacy data for the field.

254.48 – Selecting Variables for the Time Domain Spectroscopic Survey

Eric Morganson[1]
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Contributing teams: TDSS, SDSS, Pan-STARRS1

The Time Domain Spectroscopic Survey is an eBOSS subprogram that will obtain spectroscopy for 400,000 objects that vary more than 0.1 magnitudes. 100,000 of these objects will be unique to TDSS and 300,000 will be shared with other subprograms. We use a combination of Pan-STARRS1 and SDSS photometry to select a sample of variables that is 95% pure and 60% complete. This sample is obtained with three dimension Kernel Density Analysis. Our data and method are particularly effective at selecting long term variables, and more than 300,000 of our variables will be quasars.

254.49 – Structural Evolution of Early-type Galaxies to z=2.5 in CANDELS

Yu-Yen Chang[1], Arjen van der Wel[1], Hans-Walter Rix[1]
1. Max Planck Institute for Astronomy, Heidelberg, Germany.
Contributing teams: The CANDELS collaboration

Projected axis ratio measurements of 880 early-type galaxies at redshifts 1 < z < 2.5 selected from CANDELS are used to reconstruct and model their intrinsic shapes. The sample is selected on the basis of multiple rest-frame colors to reflect low star-formation activity. Similar to their present-day counterparts, the z > 1 early-type galaxies show a variety of intrinsic shapes; even at a fixed mass, the projected axis ratio distributions cannot be explained by the random projection of a set of galaxies with very similar intrinsic shapes. However, a two-population model for the intrinsic shapes, consisting of a triaxial, fairly round population, combined with a flat (c/a ~ 0.3) oblate population, adequately describes the projected axis ratio distributions of both present-day and z > 1 early-type galaxies. However, the oblate fraction among massive ($M^* \sim 10^{11}$ Msun) objects was much higher in the past: 0.59 ± 0.10 at z > 1, compared to 0.20 ± 0.02 at z ~ 0.1. When combined with previous findings that the number density and sizes of early-type galaxies substantially increase over the same redshift range, this can be explained by the gradual emergence of merger-produced elliptical galaxies, at the expense of the destruction of pre-existing disks that were common among their high-redshift progenitors.

255 – Computation, Data Handling, & Image Analysis Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

255.01 – The LCOGT Observation Portal, Data Pipeline and Science Archive

Tim Lister[1]
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Contributing teams: LCOGT Science Archive Team

Las Cumbres Observatory Global Telescope (LCOGT) is building and deploying a world-wide network of optical telescopes dedicated to time-domain astronomy. During 2012-2013, we successfully deployed and commissioned nine new 1m telescopes at McDonald Observatory (Texas), CTIO (Chile), SAAO (South Africa) and Siding Spring Observatory (Australia). New, improved cameras and additional telescopes will be deployed during 2014. To enable the diverse LCOGT user community of scientific and educational users to request observations on the LCOGT Network and to see their progress and get access to their data, we have developed an Observation Portal system. This Observation Portal integrates proposal submission and observation requests with seamless access to the data products from the data pipelines in near-realtime and long-term products from the Science Archive. We describe the LCOGT Observation Portal and the data pipeline, currently in operation, which makes use of the ORAC-DR automated recipe-based data reduction pipeline and illustrate some of the new data products. We also present the LCOGT Science Archive, which is being developed in partnership with the Infrared Processing and Analysis Center (IPAC) and show some of the new features the Science Archive provides.

255.02 – The ADS All Sky Survey: footprints of astronomy literature, in the sky

Alberto Pepe[1], Alyssa A. Goodman[1], August A. Muench[1]
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Contributing teams: Seamless Astronomy Group at the CfA

The ADS All-Sky Survey (ADSASS) aims to transform the NASA Astrophysics Data System (ADS), widely known for its unrivaled value as a literature resource for astronomers, into a data resource. The ADS is not a data repository per se, but it implicitly contains valuable holdings of astronomical data, in the form of images, tables and object references contained within articles. The objective of the ADSASS effort is to extract these data and make them discoverable and available through existing data viewers. In this talk, the ADSASS viewer - http://adsass.org/ - will be presented: a sky heatmap of astronomy articles based on the celestial objects they reference. The ADSASS viewer is as an innovative research and visual search tool for it allows users to explore astronomical literature based on celestial location, rather than keyword string. The ADSASS is a NASA-funded initiative carried out by the Seamless Astronomy Group at the Harvard-Smithsonian Center for Astrophysics.

255.03 – Introducing ADS 2.0

Alberto Accomazzi[1], Michael J. Kurtz[1], Edwin A. Henneken[1], Carolyn S. Grant[1], Donna Thompson[1], James Luker[1], Roman Chyla[1], Stephen S. Murray[1]
1. Harvard Smithsonian, CfA, Cambridge, MA, United States.

In the spring of 1993, the Smithsonian/NASA Astrophysics Data System (ADS) first launched its bibliographic search system. It was known then as the ADS Abstract Service, a component of the larger Astrophysics Data System effort which had developed an interoperable data system now seen as a precursor of the Virtual Observatory. As a result of the massive technological and sociological changes in the field of scholarly communication, the ADS is now completing the most ambitious technological upgrade in its twenty-year history. Code-named ADS 2.0, the new system features: an IT platform built on web and digital library standards; a new, extensible, industrial strength search engine; a public API with various access control capabilities; a set of applications supporting search, export, visualization, analysis; a collaborative, open source development model; and enhanced indexing of content which includes the full-text of astronomy and physics publications. The changes in the ADS platform affect all aspects of the system and its operations, including: the process through which data and metadata are harvested, curated and indexed; the interface and paradigm used for searching the database; and the follow-up analysis capabilities available to the users. This poster describes the choices behind the technical overhaul of the system, the technology stack used, and the opportunities which the upgrade is providing us with, namely gains in productivity and enhancements in our system capabilities.

255.04 – Virtual Astronomy: The Legacy of the Virtual Astronomical Observatory

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Contributing teams: VAO Project Team

Over the past ten years, the Virtual Astronomical Observatory (VAO, http://usvao.org) and its predecessor, the National Virtual Observatory (NVO), have developed and operated a software infrastructure consisting of standards and protocols for data and science software applications. The Virtual Observatory (VO) makes it possible to develop robust software for the discovery, access, and analysis of astronomical data. Every major publicly funded research organization in the US and worldwide has deployed at least some components of the VO infrastructure; tens of thousands of VO-enabled queries for data are invoked daily against catalog, image, and spectral data collections; and groups within the community have developed tools and applications building upon the VO infrastructure. Further, NVO and VAO have helped ensure access to data internationally by co-founding the International Virtual Observatory Alliance (IVOA, http://ivoa.net). The products of the VAO are being archived in a publicly accessible repository. Several science tools developed by the VAO will continue to be supported by the organizations that developed them: the Iris spectral energy distribution package (SAO), the Data Discovery Tool (STScI/MAST, HEASARC), and the scalable cross-comparison service (IPAC). The final year of VAO is focused on development of the data access protocol for data cubes, creation of Python language bindings to VO services, and deployment of a cloud-like data storage service that links to VO data discovery tools (SciDrive). We encourage the community to make use of these tools and services, to extend and improve them, and to carry on with the vision for virtual astronomy: astronomical research enabled by easy access to distributed data and computational resources. Funding for VAO development and operations has been provided jointly by NSF and NASA since May 2010. NSF funding will end in September 2014, though with the possibility of competitive solicitations for VO-based tool development. NASA intends to maintain core VO services such as the resource registry (the index of VO-accessible data collections), monitoring services, and a website as part of the remit of HEASARC, IPAC (IRSA, NED), and MAST.

255.05 – Accessing Multi-Dimensional Images and Data Cubes in the Virtual Observatory

Douglas Tody[1, 10], Raymond L. Plante[2, 10], G. B. Berriman[3, 10], Mark Cresitello-Dittmar[4, 10], John Good[3, 10], Matthew Graham[5, 10], Gretchen Greene[6, 10], Robert J. Hanisch[6, 10], Timothy Jenness[7, 10], Joseph Lazio[8, 10], Pat Norris[9, 10], Olga Pevunova[3, 10], Arnold H. Rots[4, 10]
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Telescopes across the spectrum are routinely producing multi-dimensional images and datasets, such as Doppler velocity cubes, polarization datasets, and time-resolved "movies." Examples of current telescopes producing such multi-dimensional images include the JVLA, ALMA, and the IFU instruments on large optical and near-infrared wavelength telescopes. In the near future, both the LSST and JWST will also produce such multi-dimensional images routinely. High-energy instruments such as Chandra produce event datasets that are also a form of multi-dimensional data, in effect being a very sparse multi-dimensional image. Ensuring that the data sets produced by these telescopes can be both discovered and accessed by the community is essential and is part of the mission of the Virtual Observatory (VO). The Virtual Astronomical Observatory (VAO, http://www.usvao.org/), in conjunction with its international partners in the International Virtual Observatory Alliance (IVOA), has developed a protocol and an initial demonstration service designed for the publication, discovery, and access of arbitrarily large multi-dimensional images. The protocol describing multi-dimensional images is the *Simple Image Access Protocol*, version 2, which provides the minimal set of metadata required to characterize a multi-dimensional image for its discovery and access. A companion *Image Data Model* formally defines the semantics and structure of multi-dimensional images independently of how they are serialized, while providing capabilities such as support for sparse data that are essential to deal effectively with large cubes. A prototype data access service has been deployed and tested, using a suite of multi-dimensional images from a variety of telescopes. The prototype has demonstrated the capability to discover and remotely access multi-dimensional data via standard VO protocols. The prototype informs the specification of a protocol that will be submitted to the IVOA for approval, with an operational data cube service to be delivered in mid-2014. An associated user-installable VO data service framework will provide the capabilities required to publish VO-compatible multi-dimensional images or data cubes.

255.06 – Software Reproduceability for Science Data

Peter J. Teuben[1], Lee G. Mundy[1], Shaye Storm[1], Leslie Looney[2], Katherine Lee[1,2], Manuel Fernandez Lopez[2]
1. Univ. of Maryland, College Park, MD, United States. 2. University of Illinois, Urbana-Champaign, IL, United States.

The case of a complex multi-track radio interferometric data set with combined single dish data has been used in a simple pipeline to discuss issues around software reproduceability for a specific science dataset. Results from the CARMA CLASSy project have been presented at a number of posters and talks at this meeting, and in this poster we specifically highlight some of the lessons learned in operating our pipeline and in particular how this teaches us about software reproduceability.

255.07 – Quantifying Deep-Imaging Limits of the VLA

Julia Mayeshiba[1,2], Julia Mayeshiba[1,2], Urvashi Rau[1], Frazer N. Owen[1]
1. National Radio Astronomy Observatory, Socorro, NM, United States. 2. University of Wisconsin - Madison, Madison, WI, United States.

The confusion limit is important to understand when conducting surveys of faint radio sources. The source count distributions derived from these surveys are indicative of the large-scale structure and evolution of the universe. The VLA's confusion limit is not well-defined and astronomers have frequently observed below its current estimated confusion limit. Our study seeks to refine and understand these estimated values and their differences. In our study, we used sources from the center one square degree of the S^3-SEX simulated sky made by Wilman et al. As a first step, we verified that our simulation matched observed trends of the confusion limit. During this process we studied the dependence of the achieved confusion limit on cleaning depth and PSF shape. We also reproduced the different limits seen by Frazer Owen in 2008 and NVSS. With this check completed, we then roughly estimated the confusion limits for the VLA's four configurations. Our preliminary results showed that at an observing frequency of 1.4GHz , there is a confusion limit of 10µJy for the D Configuration and 5µJy for the C Configuration. These estimates are a factor of two lower than the lowest confusion limits reached by observers. While it is encouraging that our estimated confusion limits follow observed trends, more analysis of our process is needed. We could not accurately estimate confusion limits for the A and B configurations due to an artifact dominated image in the A Configuration and an estimated confusion limit that was too close to the noise level in the B Configuration. For the second part of our study we tested CASA's source-finding algorithm. We found that as currently implemented, it has significant difficulty finding fainter sources.

255.08 – Extracting information using Spitzer IRAC color analysis

Jason E. Ybarra[1], Carlos Román-Zuñíga[1], Kim Arvidsson[2], Grace A. Wolf-Chase[3], Elizabeth A. Lada[4]
1. Instituto de Astronomía, UNAM, Ensenada, Baja California, Mexico. 2. Schreiner Univ., Kerrville, TX, United States. 3. Adler Planetarium, Chicago, IL, United States. 4. Univ. of Florida, Gainesville, FL, United States.

In the field of star formation, *Spitzer* photometry has been used to identify and classify young pre-main sequence stars. However, the information the data provide is not limited to studying the stellar content of these regions. Previous studies have shown that the location of shocked H_2 emission in IRAC color space can be used to probe the thermal conditions of the gas. In this study we model the photometry of UV excited H_2 and PAH emission in PDR regions and present the resulting color space. We show the location of this emission depends on density and external flux. We construct a diagnostic color space diagram and show examples of its utility. JY acknowledges partial support from PAPPIT-IN101813.

255.09 – Image reduction of multi-chip near-IR data using the THELI pipeline

Karianne Holhjem[1]
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In this this poster I present a step-by-step guide to reducing multi-chip data using the THELI pipeline, focusing on near-infrared data taken with the Spartan camera on the Southern Astrophysical Research (SOAR) telescope. The goal is to provide the reader with sufficient information to reduce data on their own using THELI. For hands-on illustration I reduce 2 different data set. The first seeks to detect an extended object in the near-IR, (which has so far only been seen in narrow-band optical imaging,) thus the images contain a target covering ~25% of one of Spartan's 4 detectors. The goal of the second data set is to determine accurate photometric zeropoints for each detector, and is comprised of observations of several photometric standard stars at different airmass.

255.10 – Automating OSIRIS Data Reduction for the Keck Observatory Archive

Hien D. Tran[1], Jen Holt[1], Robert W. Goodrich[1], James E. Lyke[1], Christopher R. Gelino[2], G. B. Berriman[2]

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Contributing teams: KOA Team

Since the end of 2013, the Keck Observatory Archive (KOA) has served data from all active instruments on the Keck Telescopes. OSIRIS (OH-Suppressing Infra-Red Imaging Spectrograph), the last active instrument to be archived in KOA, has been in use behind the adaptive optics (AO) system at Keck since February 2005. It uses an array of tiny lenslets to simultaneously produce spectra at up to 4096 locations. Due to the complicated nature of the OSIRIS raw data, the OSIRIS team developed a comprehensive data reduction program. This data reduction system has an online mode for quick real-time reductions which are used primarily for basic data visualization and quality assessment done at the telescope while observing. The offline version of the data reduction system includes an expanded reduction method list, does more iterations for a better construction of the data cubes, and is used to produce publication-quality products. It can also use reconstruction matrices that are developed after the observations were taken, and are more refined. The KOA team is currently utilizing the standard offline reduction mode to produce quick-look browse products for the raw data. Users of the offline data reduction system generally use a graphical user interface to manually setup the reduction parameters. However, in order to reduce and serve the ~200,000 science files on disk, all of the reduction parameters and steps need to be fully automated. This pipeline will also be used to automatically produce quick-look browse products for future OSIRIS data after each night's observations. Here we discuss the complexities of OSIRIS data, the reduction system in place, methods for automating the system, performance using virtualization, and progress made to date in generating the KOA products.

255.11 – Examining the Point Spread Function Using the Active Optics System on DECam

Christopher Davis[1, 2], Aaron Roodman[2, 1]

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Contributing teams: Dark Energy Survey

The Dark Energy Survey (DES) recently began its five-year 5000 square degree survey of the southern sky with the 570-Megapixel Dark Energy Camera (DECam) on the Blanco 4-meter telescope at the Cerro Tololo Interamerican Observatory. Using several different probes, it will examine the parameters and possible variation of dark energy. On the DECam is an Active Optics System (AOS) which uses inter- and intrafocal chips to correct the defocus, decenter, and tip and tilt of the focal plane. The Zernike formalism -- a polynomial basis for images with coefficients that correspond to classical optical aberrations -- used in the DECam AOS may also be applied to the analysis and prediction of the variation in the Point Spread Function (PSF) magnitude and ellipticity across the focal plane. A deep understanding of the PSF is vital for analyses which rely on precise morphology measurements, such as weak gravitational lensing and cosmic shear measurements. The Zernike formalism provides a physical basis for the determination of the PSF that accounts for the optical system, first order effects from atmospheric seeing, and common mode PSF ellipticities. Here, we describe the results of preliminary attempts to predict the PSF from this formalism. We examine its strengths and weaknesses, and discuss potential future implementation into weak lensing pipelines.

255.12 – Instrument Performance Monitoring at Gemini North

Kimberly Emig[1], Michael Pohlen[2], Andre-Nicolas Chene[2]

1. Arizona State University, Tempe, AZ, United States. 2. Gemini Observatory, North, Hilo, HI, United States.

An instrument performance monitoring (IPM) project at the Gemini North Observatory evaluates the delivered throughput and sensitivity of, among other instruments, the Near-Infrared Integral Field Spectrometer (NIFS), the Gemini Near-Infrared Spectrograph (GNIRS), and the Gemini Multi-Object Spectrograph (GMOS-N). Systematic observations of standard stars allow the quality of the instruments and mirror to be assessed periodically. An automated pipeline has been implemented to process and analyze data obtained with NIFS, GNIRS cross-dispersed (XD) and long slit (LS) modes, and GMOS (photometry and spectroscopy). We focus the discussion of this poster on NIFS and GNIRS. We present the spectroscopic throughput determined for ZJHK bands on NIFS, the XJHKLM band for GNIRS XD mode and the K band for GNIRS LS. Additionally, the sensitivity is available for the JHK bands in NIFS and GNIRS XD, and for the K band in GNIRS LS. We consider data taken as early as March 2011. Furthermore, the pipeline setup and the methods used to determine throughput and sensitivity are described.

255.13 – Automated classification of Chandra X-ray sources

Derek Brehm[1], Oleg Kargaltsev[1], Blagoy Rangelov[1], Igor Volkov[1], George G. Pavlov[2]
1. The George Washington University, Washington, DC, United States. 2. Pennsylvania State University, University Park, PA, United States.

With the advent of the latest generation X-ray telescopes there has been a major influx of data associated with the detection of hundreds of thousands X-ray sources. As one can rarely tell a source type from its X-ray properties alone, the full potential of the X-ray catalogs can only be unlocked by correlating multiwavelength (MW) properties via cross-identification with other surveys. However, one would spend an enormous amount of time classifying these objects by their physical nature if the classification was to be done on a source-by-source basis by humans. Therefore, we are using a supervised learning algorithm to classify sources detected by the Chandra X-ray Observatory. The classifications are based on a training dataset which currently includes about 7,000 X-ray sources of known nature (main sequence stars, Wolf-Rayet stars, young stars, active galactic nuclei, low mass X-ray binaries, high mass x-ray binaries, and neutron stars). For each source, the training dataset includes up to 24 multiwavelength properties. The efficiency and accuracy of the classification is verified by dividing the training dataset in two and performing cross-validation. The results are also inspected by plotting source properties in 2D slices of the parameter space. As an application of our automated procedure we classified unidentified sources in the supernova remnant (SNR) G352.7-0.1, in the field of HESS J1809-193, and in part of the Chandra Source Catalog 1.0. We present the results of the verification tests and the classification results. This research was partially supported by NASA/SAO grant AR3-14017X.

255.14 – Neutrino-Gamma Multi-Messenger Source Detection via the Astrophysical Multi-Messenger Observatory Network

Josh Fixelle[1], Smith Miles[1]
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Contributing teams: AMON

The idea of multi-messenger event detection has long been explored in the context of above-threshold analysis performed by the IceCube collaboration using Swift BAT and by the Amanda collaboration using BATSE. While these investigations produced null results, they left the event space of sub-threshold events untouched. This untapped event space, combined with the addition of new observatories for various bands and messenger types, provides the obvious niche for a GBN style network to exist: AMON. We consider Monte-carlo models of pair-wise detection between sub-threshold IceCube neutrino doublets, sub-threshold neutrino-gamma doublets with Swift BAT, and with sub-threshold higher multiplicity neutrino-gamma coincidences with Fermi LAT. Several detection methods were considered and compared to the status quo analyses of neutrino doublets by IceCube, demonstrating significant sensitivity gain. The MC model analysis was followed by an archival doublet analysis between IceCube-40 and Fermi LAT data within their co-temporal window of observation. Several methods for detecting statistical signal excess in the archival analysis were considered, providing an upper limit on source population parameters for the given analysis sensitivity.

255.15 – Constraining Very High-Energy Gamma Ray Sources Using IceCube Neutrino Observations

Gregory Vance[2,1], Jacob Feintzeig[1], Albrecht Karle[1]
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Contributing teams: IceCube Collaboration

Modern gamma ray astronomy has revealed the most violent, energetic objects in the known universe, from nearby supernova remnants to distant active galactic nuclei. In an effort to discover more about the fundamental nature of such objects, we present searches for astrophysical neutrinos in coincidence with known gamma ray sources. Searches were conducted using data from IceCube Neutrino Observatory, a cubic-kilometer neutrino detector that is sensitive to astrophysical particles with energies above 1 TeV. The detector is situated at the South Pole, and uses more than 5,000 photomultiplier tubes to detect Cherenkov light from the interactions of particles within the ice. Existing models of proton-proton interactions allow us to link gamma ray fluxes to the production of high-energy neutrinos, so neutrino data from IceCube can be used to constrain the mechanisms by which gamma ray sources create such energetic photons. For a few particularly bright sources, such as the blazar Markarian 421, IceCube is beginning to reach the point where actual constraints can be made. As more years of data are analyzed, the limits will improve and stronger constraints will become possible. This work was supported in part by the National Science Foundation's REU Program through NSF Award AST-1004881 to the University of Wisconsin-Madison.

255.16 – Scalable Machine Learning for Massive Astronomical Datasets

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Contributing teams: Canadian Astronomy Data Centre

We present the ability to perform data mining and machine learning operations on a catalog of half a billion astronomical objects. This is the result of the combination of robust, highly accurate machine learning algorithms with linear scalability that renders the applications of these algorithms to massive astronomical data tractable. We demonstrate the core algorithms kernel density estimation, K-means clustering, linear regression, nearest neighbors, random forest and gradient-boosted decision tree, singular value decomposition, support vector machine, and two-point correlation function. Each of these is relevant for astronomical applications such as finding novel astrophysical objects, characterizing artifacts in data, object classification (including for rare objects), object distances, finding the important features describing objects, density estimation of distributions, probabilistic quantities, and exploring the unknown structure of new data. The software, Skytree Server, runs on any UNIX-based machine, a virtual machine, or cloud-based and distributed systems including Hadoop. We have integrated it on the cloud computing system of the Canadian Astronomical Data Centre, the Canadian Advanced Network for Astronomical Research (CANFAR), creating the world's first cloud computing data mining system for astronomy. We demonstrate results showing the scaling of each of our major algorithms on large astronomical datasets, including the full 470,992,970 objects of the 2 Micron All-Sky Survey (2MASS) Point Source Catalog. We demonstrate the ability to find outliers in the full 2MASS dataset utilizing multiple methods, e.g., nearest neighbors, and the local outlier factor. 2MASS is used as a proof-of-concept dataset due to its convenience and availability. These results are of interest to any astronomical project with large and/or complex datasets that wishes to extract the full scientific value from its data.

255.17 – GREAT3: The Third Gravitational Lensing Accuracy Testing Challenge

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Contributing teams: the Great3 collaboration

We describe the ongoing weak lensing community data challenge, GREAT3, and the associated open-source image simulation software, GalSim. The GREAT3 challenge tests the impact on weak lensing measurements of (a) realistic galaxy morphologies, (b) realistic uncertainty in the point-spread function estimation, and (c) the need to combine multiple exposures when estimating the galaxy shape. It includes simulated ground- and space-based data. The tests of realistic galaxy morphologies rely on a training set of galaxies from the Hubble Space Telescope, a subset of which has been publicly released for community use, with the remainder to be released at the end of the challenge. We describe some technical considerations for generating the challenge data and for testing weak lensing measurements with the next generation of weak lensing surveys, such as DES, HSC, KIDS, and Pan-STARRS.

255.18 – Electron-Impact Uncertainty Analysis and its Impact on Certain Temperature Diagnostics

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1. Auburn University, Auburn , AL, United States.

In this study we calculate the electron-impact uncertainties in atomic data for direct ionization and recombination and investigate the role of these uncertainties on spectral diagnostics. We outline a systematic approach to assigning meaningful uncertainties that vary with electron temperature. Once these uncertainty parameters have been evaluated, we can then calculate the uncertainties on key diagnostics through a Monte Carlo routine, using the Astrophysical Emission Code (APEC) [Smith et al. 2001]. We incorporate these uncertainties into well known temperature diagnostics, such as the Lyman alpha versus resonance line ratio and the G ratio. We compare these calculations to a study performed by [Testa et al. 2004], where significant discrepancies in the two diagnostic ratios were observed. We conclude that while the atomic physics uncertainties play a noticeable role in the discrepancies observed by Testa, they do not explain all of them. This indicates that there is another physical process occurring in the system that is not being taken into account. This work is supported in part by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.

255.19 – Exploring How Different Mass-loss Schemes Influence the Properties of Nascent White Dwarfs

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At the end of their lives, the majority of stars in the universe will evolve to become white dwarfs. Despite this fact, the

physical processes governing mass loss during post-main-sequence evolution and their impact on the properties of the nascent white dwarf are not well understood. Using the open-source code Modules for Experiments in Stellar Astrophysics (MESA), we explore how commonly used mass-loss prescriptions influence the properties of the remnant white dwarf for progenitors with zero-age-main-sequence masses less than 3 Msun. Our results are compared to observational constraints on the initial-final mass relation and provide guidance for future studies of post-main-sequence-stellar-evolution for low-mass stars.

255.20 – Relation between star formation and AGN activity in typical elliptical galaxies: Analysis of the 2MASS K-band galaxy images

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We are carrying out a program of aperture photometry on typical elliptical galaxies. While there are many ways to calculate the and magnitude, we are going to use the Aperture Photometry Tool (APT) GUI and the program IRAF (Image Reduction and Analysis Facility). By looking at a sample of 236 galaxies from the 2MASS survey k-band, it was determined that 68 of the galaxies needed some sort of a pixel blocking technique due to unwanted background stars or galaxies that may interfere with our readings. My job is to determine a way to block out these pixels while not compromising the true from the galaxy.

255.21 – Difference Image Analysis of De-Focused 2009 CSTAR Observations

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Contributing teams: PLATO, CSTAR

The Chinese Small Telescope ARray (CSTAR) carried out high-cadence time-series observations of a 27-square degree region centered on the South Celestial Pole during the Antarctic winter seasons of 2008, 2009 and 2010. Analysis of the 2008 and 2010 data using aperture photometry resulted in the discovery of 198 variables with i < 15.3 mag. Routine servicing completed after the 2008 winter season left the telescope out of focus for the 2009 winter season. The telescope also suffered a power loss after ~2 months of observation. In spite of the telescope's technical issues, nearly 250,000 usable images were taken in the 'g', 'N', and 'r' bands. We used a combination of difference imaging and aperture photometry to compensate for the highly crowded, blended and out of focus images. We are able to recover more than 100 of the variables in the 'g'-band and have discovered about 20 objects to be explored further. We discuss the analysis of all of these objects in the 'N' and 'r' bands as well. We also present the preliminary results of the application of this technique to another time-series data set taken from Tolar Grande, Argentina during the 2013 southern winter. Ryan J. Oelkers would like to acknowledge the support of a grant from the George P. and Cynthia Woods Mitchell Institute for Fundamental Physics & Astronomy.

255.22 – ANALYSIS OF PHOTOMETRIC EFFICIENCY AND ACCURACY OF THE IDL PROCUDURE, PHAST

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PhAst (Photometry and Astrometry) is an IDL program designed to measure the photometry and astrometry of near Earth objects (NEOs) from CCD observations by ground-based telescopes. The goal of PhAst is to simplify the observation of NEOs and the reporting of their characteristics to the International Astronomical Union's Minor Planetary Center with a focus on NEO astrometry. We compared the photometric results of PhAst against results derived using the photometry procedures in the Image Reduction and Analysis Facility (IRAF). We used CCD observations of Landolt standard stars that were obtained with the 2.1-m telescope at the Kitt Peak National Observatory. We found the photometry from PhAst to be on average nearly identical to the photometry derived using IRAF. PhAst can be considered reliable when measuring the magnitude of a NEO. Kutsop was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program (AST-1262829).

255.23 – Visualizing Astronomical Data with Blender

Brian R. Kent[1]
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We present methods for using the 3D graphics program Blender in the visualization of astronomical data. The software's forte for animating 3D data lends itself well to use in astronomy. The Blender graphical user interface and Python scripting capabilities can be utilized in the generation of models for data cubes, catalogs, simulations, and surface maps. We review

methods for data import, 2D and 3D voxel texture applications, animations, camera movement, and composite renders. Rendering times can be improved by using graphic processing units (GPUs). A number of examples are shown using the software features most applicable to various kinds of data paradigms in astronomy.

255.24 – Astropy: Community Python Software for Astronomy

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Contributing teams: Astropy Developers

The Astropy Project is a community effort to develop an open source Python package of common data structures and routines for use by other, more specialized astronomy software in Python in order to foster software interoperability in the astronomical community. The project encompasses Astropy's "core" and "affiliated" packages that adopt Astropy's coding, testing and documentation standards. By doing so we aim to improve interoperability with other Python packages in astronomy, and help a broader community implement more Pythonic solutions to astronomy computing problems while minimizing duplication of effort. The project provides a template for other projects that use Astropy to reuse much of Astropy's development framework without reinventing the wheel. Here we present an overview of the key features of the core package (existing and upcoming), current and planned affiliated packages, and how we manage a large open source project with a diverse community of contributors.

255.25 – You've Written a Cool Astronomy Code! Now What Do You Do with It?

Alice Allen[1], Alberto Accomazzi[2], G. B. Berriman[3], Kimberly DuPrie[1], Robert J. Hanisch[4], Jessica D. Mink[5], Robert J. Nemiroff[6], Lior Shamir[7], Keith Shortridge[8], Mark B. Taylor[9], Peter J. Teuben[10], John F. Wallin[11]
1. Astrophysics Source Code Library, Calverton, MD, United States. 2. Smithsonian Astrophysical Observatory, Cambridge, MA, United States. 3. Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA, United States. 4. Space Telescope Science Institute/Virtual Astronomical Observatory, Baltimore, MD, United States. 5. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 6. Michigan Technological University, Houghton, MI, United States. 7. Lawrence Technological University, Southfield, MI, United States. 8. Australian Astronomical Observatory, North Ryde, NSW, Australia. 9. University of Bristol, Bristol, United Kingdom. 10. University of Maryland, College Park, MD, United States. 11. Middle Tennessee State University, Murfreesboro, TN, United States.

Now that you've written a useful astronomy code for your soon-to-be-published research, you have to figure out what you want to do with it. Our suggestion? Share it! This presentation highlights the means and benefits of sharing your code. Make your code citable -- submit it to the Astrophysics Source Code Library and have it indexed by ADS! The Astrophysics Source Code Library (ASCL) is a free online registry of source codes of interest to astronomers and astrophysicists. With over 700 codes, it is continuing its rapid growth, with an average of 17 new codes a month. The editors seek out codes for inclusion; indexing by ADS improves the discoverability of codes and provides a way to cite codes as separate entries, especially codes without papers that describe them.

255.26 – Data publication and sharing using the SciDrive service

Dmitry Mishin[1], Dmitry Medvedev[1], Alexander S. Szalay[1], Raymond L. Plante[2]
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Despite the last years progress in scientific data storage, still remains the problem of public data storage and sharing system for relatively small scientific datasets. These are collections forming the "long tail" of power log datasets distribution. The aggregated size of the long tail data is comparable to the size of all data collections from large archives, and the value of data is significant. The SciDrive project's main goal is providing the scientific community with a place to reliably and freely store such data and provide access to it to broad scientific community. The primary target audience of the project is astoromy community, and it will be extended to other fields. We're aiming to create a simple way of publishing a dataset, which can be then shared with other people. Data owner controls the permissions to modify and access the data and can assign a group of users or open the access to everyone. The data contained in the dataset will be automaticaly recognized by a background process. Known data formats will be extracted according to the user's settings. Currently tabular data can be automatically extracted to the user's MyDB table where user can make SQL queries to the dataset and merge it with other public CasJobs resources. Other data formats can be processed using a set of plugins that upload the data or metadata to user-defined side services. The current implementation targets some of the data formats commonly used by the astronomy communities, including FITS, ASCII and Excel tables, TIFF images, and YT simulations data archives. Along with generic metadata, format-

specific metadata is also processed. For example, basic information about celestial objects is extracted from FITS files and TIFF images, if present. A 100TB implementation has just been put into production at Johns Hopkins University. The system features public data storage REST service supporting VOSpace 2.0 and Dropbox protocols, HTML5 web portal, command-line client and Java standalone client to synchronize a local folder with the remote storage. We use VAO SSO (Single Sign On) service from NCSA for users authentication that provides free registration for everyone.

255.27 – A Mobile Data Application for the Fermi Mission

Thomas E. Stephens[1]
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Contributing teams: Fermi Science Support Center

With the ever increasing use of smartphones and tablets among scientists and the world at large, it becomes increasingly important for projects and missions to have mobile friendly access to their data. This access could come in the form of mobile friendly websites and/or native mobile applications that allow the users to explore or access the data. The Fermi Gamma-ray Space Telescope mission has begun work along the latter path. In this poster I present the current version of the Fermi Data Portal, a native mobile application for both Android and iOS devices that allows access to various high level public data products from the Fermi Science Support Center (FSSC), the Gamma-ray Coordinate Network (GCN), and other sources. While network access is required to download data, most of the data served by the app are stored locally and are available even when a network connection is not available. This poster discusses the application's features as well as the development experience and lessons learned so far along the way.

255.28 – Understanding and Using the Fermi Science Tools

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Contributing teams: Fermi Science Support Center

The Fermi Science Support Center (FSSC) provides information, documentation, and tools for the analysis of Fermi science data, including both the Large-Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). Source and binary versions of the Fermi Science Tools can be downloaded from the FSSC website, and are supported on multiple platforms. An overview document, the Cicerone, provides details of the Fermi mission, the science instruments and their response functions, the science data preparation and analysis process, and interpretation of the results. Analysis Threads and a reference manual available on the FSSC website provide the user with step-by-step instructions for many different types of data analysis: point source analysis - generating maps, spectra, and light curves, pulsar timing analysis, source identification, and the use of python for scripting customized analysis chains. We present an overview of the structure of the Fermi science tools and documentation, and how to acquire them. We also provide examples of standard analyses, including tips and tricks for improving Fermi science analysis.

255.29 – A Search on the Internet for Evidence of Time Travel

Robert J. Nemiroff[1], Teresa Wilson[1]
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Time travel has captured the public imagination for much of the past century, but few searches for evidence of time travel have ever been done. Here three searches on the Internet for evidence of time travel are described, all three seeking a prescient mention of information not available before a given date. The first investigation sought prescient content placed on the Internet, highlighted by a comprehensive search for specific terms in tweets on Twitter. The second investigation sought prescient inquiries submitted to a search engine, highlighted by a comprehensive search for specific search terms submitted to the Astronomy Picture of the Day (APOD) web site. The third investigation involved a request for a direct Internet communication, either by email or tweet, pre-dating to the time of the inquiry. Given practical verifiability concerns, only time travel from the future was investigated. The main terms searched for involved Comet ISON and Pope Francis, as they became popular during our search window -- between 2006 and 2013. No evidence for time travel was discovered. Although these negative results do not disprove time travel, given the great reach of the Internet, this search is perhaps the most comprehensive to date.

255.30 – Detection of a Small Fast Moving Near Earth Asteroid with Synthetic Tracking

Michael Shao[1], Chengxing Zhai[1], Thomas Werne[1], Bijan Nemati[1], Leon K. Harding[2], Gregg Hallinan[2]
1. JPL, pasadena, CA, United States. 2. Caltech, Pasadena, CA, United States.

We report the detection of a small Near Earth Asteroid, at an apparant magnitudeof 23.0, moving 5.8 deg/day, with the

Chimera camera on the Palomar 5m telescope. If this object had been observed with a normal 30sec CCD exposure, the streak would be 7.25 arcsec long and the surface brightness of the streak would be equal to a 25.2mag star. The synthetic tracking data was taken with an EMCCD camera at 15 frames/sec, while the telescoe was moving slightly slower than sidereal rate, so the field of view would drift 2.5arcmin in 30 sec. The camera had a 2.5arcmin field of view. This drift scan would continue for ~1hr surveying a 5 deg*2.5arcmin patch of the sky for Near Earth Asteroids. 1 hr later the same patch of the sky was scanned again to provide a confiming observation. Over 2 night we surveyed a 1.25 sqdeg area of the sky. The data was analyzed using a shift/add algorithm where each successive image in the 450 frame data set was shifted to match the velocity of the Asteroid. Since we did not know the velocity of the asteroid, shift/add was performed with 2500 different velocities in a NVidia GPU.. The NEA was detected twice ~1hr apart with a SNR~15 each time, the NEA had moved ~1000 arcsec during that hour. The synthetic tracking algorithm produces position, velocity and brightness for each 30sec observation. The position of the NEA in the 2nd observation was consistent with the position and velocity of the 1st observation. We could not solve for an orbit with just two observations, but if the transverse velocity of the NEA was 10km/s, then this object would have been an H=29 mag NEA detected at a distance of 20 lunar distances, ~8m in diameter. This expected number of NEA detections for these two nights of observing was 1.5 objects fainter than H>28mag. A future upgraded version of this camera with a 25arcmin field of view could potentially detect ~150 small H>28mag NEA's per night. This can be compared to ~150 H>28mag NEA's discovered over the last 5 years from all currently facilities.

255.31 – A Method to Automate Identification of Spiral Arms in Galaxies

Christina K. Lacey[1], Kevin Mercer[1]
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We present our preliminary results in identifying the spiral arms of NGC 6946 using a nearest-neighbors analysis. NGC 6946 is grand design spiral galaxy with well-defined arms. The spiral arms were previously identified in an Hα image and traced out by Matonick, D. et al., ApJS, 113, 333, (1997) by visual inspection. We want to develop a computer algorithm that will identify the spiral arms automatically. Once the spiral arms have been found digitally, we can use this information to compare the spiral arms with the locations of compact objects such as supernova remnants and perform statistical tests, for example, to determine if the supernova remnants are associated with the spiral arms. We are using the publicly available program PyFITS, a development project of the Science Software Branch at the Space Telescope Science Institute (STScI) that is available for software download from STScI, to perform a computer-based image analysis. We have written python macros that interact with the already written image manipulation and display features of PyFITS to perform the image analysis and implement a nearest-neighbors algorithm to identify and link the centers of the high emission regions from the spiral arm regions. Our code currently identifies the centers of the high emission regions, but more work is needed to link up these sites and draw out the spiral arms. Future work includes improving the code to better identify spiral arms and converting the code to work on the Astropy, a community-developed core Python package for Astronomy (Robitaille, T. P., et al. A&A 558, A33, 2013).

255.32 – Synergy with HST and JWST Data Management Systems

Gretchen Greene[1]
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Contributing teams: Space Telescope Data Management Team

The data processing and archive systems for the JWST will contain a petabyte of science data and the best news is that users will have fast access to the latest calibrations through a variety of new services. With a synergistic approach currently underway with the STScI science operations between the Hubble Space Telescope and James Webb Space Telescope data management subsystems (DMS), operational verification is right around the corner. Next year the HST archive will provide scientists on-demand fully calibrated data products via the Mikulski Archive for Space Telescopes (MAST), which takes advantage of an upgraded DMS. This enhanced system, developed jointly with the JWST DMS is based on a new CONDOR distributed processing system capable of reprocessing data using a prioritization queue which runs in the background. A Calibration Reference Data System manages the latest optimal configuration for each scientific instrument pipeline. Science users will be able to search and discover the growing MAST archive calibrated datasets from these missions along with the other multiple mission holdings both local to MAST and available through the Virtual Observatory. JWST data systems will build upon the successes and lessons learned from the HST legacy and move us forward into the next generation of multi-wavelength archive research.

256 – Catalogs Poster Session
Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

256.01 – The Third Fermi LAT Catalog of High-Energy Gamma-ray Sources

David J. Thompson[1], Jean Ballet[2], Thompson Burnett[3]
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Contributing teams: Fermi Large Area Telescope Collaboration

The Fermi Gamma-ray Space Telescope Large Area Telescope (LAT) has been gathering science data since August 2008, surveying the full sky every three hours. The second source catalog (2FGL, Nolan et al 2012, ApJS 199, 31) was based on 2 years of data. We are preparing a third source catalog (3FGL) based on 4 years of reprocessed data. The reprocessing introduced a more accurate description of the instrument, which resulted in a narrower point spread function. Both the localization and the detection threshold for hard-spectrum sources have been improved. The new catalog also relies on a refined model of Galactic diffuse emission, particularly important for low-latitude soft-spectrum sources. The process for associating LAT sources with those at other wavelengths has also improved, thanks to dedicated multiwavelength follow-up, new surveys and better ways to extract sources likely to be gamma-ray counterparts. We describe the construction of this new catalog, its characteristics, and its remaining limitations.

256.02 – Enigmas of the Fermi-LAT Unassociated Sources

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Contributing teams: The Fermi-LAT Collaboration

Multi-wavelength observations of the bright Fermi-LAT unassociated sources have been extraordinarily successful in discovering the true nature of these powerful objects. However, a number of bright LAT sources remain unassociated, requiring a more in-depth look at their multi-wavelength properties. We discuss the spatial and broadband spectral characteristics of several of these enigmatic sources and consider the possible emission mechanisms that could produce the observed characteristics. We also discuss how the upcoming "Pass 8" revision of the LAT instrument reconstruction could improve our understanding of the full list of bright (>20 sigma) still-unassociated LAT sources.

256.03 – Pass 8: Transforming the Scientific Performance of the Fermi Large Area Telescope

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Contributing teams: on behalf of the Fermi LAT Collaboration

The event selection developed for the Fermi Large Area Telescope before launch has been periodically updated to reflect the constantly improving knowledge of the detector and the environment in which it operates. Pass 7, released to the public in August 2011, represents the most recent major iteration of this incremental process. In parallel, the LAT team has undertaken a coherent long-term effort aimed at a comprehensive revision of the entire event-level analysis, based on experience gained in the prime phase of the mission. This includes virtually every aspect of the data reduction process, from simulation of the detector to event reconstruction and background rejection. The potential improvements include (but are not limited to) a significant reduction in cosmic-ray background contamination coupled with an increased effective area, a narrower point-spread function, a better understanding of the systematic uncertainties and an extension of the energy reach for the photon analysis below 100 MeV and above a few hundred GeV. We present an overview of Pass 8 work and prospects for the near future.

256.04 – Searching for Variability in the Gamma-ray Sky using the Fermi All-sky Variability Analysis (FAVA)

Daniel Kocevski[1]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States.

Ongoing observations by the Large Area Telescope (LAT) on board the Fermi spacecraft have shown that the gamma-ray sky is populated by variable sources whose activity varies on timescale as short as a fraction of a second (gamma-ray bursts, pulsars), to days (crab Nebula, Novae), or even years (blazars). Despite the significant number of variable sources detected by the LAT on these short and long timescales, one area that remains largely unexplored are variable sources with activity on

intermediate timescales, those with significant emission fluctuations on the multi-day to week timescales. The detection of variable sources by the Fermi-LAT has also been biased against finding flaring sources in our Galaxy due to bight Galactic diffuse emission, which extends up to high Galactic latitudes and all along the Galactic plane, complicating the detection of Galactic transients on intermediate timescales. The Fermi All-sky Variability Analysis (FAVA) has been designed to overcome these issues and to provide a real time list of gamma-ray flares. We review the capabilities of the new FAVA tool and present the first FAVA catalog of flaring sources significantly detected on this previously unexplored week timescale.

256.05 – A Catalog of Stellar Targets and Calibrators for Next Generation Optical Interferometers

Sam Swihart[1], Matthew W. Muterspaugh[2], Eugenio Garcia[3, 4], Gerard van Belle[3], Keivan Stassun[4, 5]
1. University of Michigan, Ann Arbor, MI, United States. 2. Tennessee State University, Nashville, TN, United States. 3. Lowell Observatory, Flagstaff, AZ, United States. 4. Vanderbilt University, Nashville, TN, United States. 5. Fisk University, Nashville, TN, United States.

The Visible Imaging System for Interferometric Observations at the Navy Precision Optical Interferometer (VISION) outside Flagstaff, Arizona is a high-resolution, six-telescope beam combiner. VISION is capable of sub-milliarcsecond resolution in visible wavelengths allowing for images of stellar surface features, such as spots and granulation. Here we present a list of the first potential science targets as well as their respective calibrators. Approximately 2900 potential science target stars in the northern hemisphere fit the criteria of being ideal for VISION having angular sizes between 2 and 4 milliarcseconds and brighter than V=6. In order to obtain good interferometric data on these targets, it is vital to establish the system response of the instrument. This is done by observing unresolved calibrator stars with visibilities near unity. The angular sizes of these calibrators must be very accurate to obtain good visibility contrast. We used a spectral energy distribution fitting code, SEDfit, which modeled each star's angular size based on a template of the spectral type of the star obtained from the Skiff Catalogue of Stellar Spectral Classification (2009-2013). Of the nearly 2000 possible calibrators, 1485 stars have relative errors of their angular sizes less than 10%, 664 have errors less than 5%, and 37 stars have relative errors less than 2%. With this precision, our catalog will be a valuable resource for the interferometric imaging community leading to great opportunities for imaging the surface of a star other than the Sun. We acknowledge the Vanderbilt Physics and Astronomy NSF REU Program.

256.06 – Modeling Spiral Galaxy Surface Luminosity to Explain Non-Uniform Inclination Distributions

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The distribution of spiral and bar galaxy orientations is expected to be uniform. However, analysis of several major galaxy catalogs shows this is not always reflected in data. In an attempt to explain this discrepancy, we have developed a galaxy simulation code to compute the appearance of a spiral type galaxy as a function of its morphological parameters. We examine the dependence of observed brightness upon inclination angle by using smooth luminous mass density and interstellar medium (ISM) density distributions. The luminous mass component is integrated along a particular line of sight, thus producing a mass distribution, from which a surface luminosity profile is derived. The ISM component is integrated alongside the luminous mass component to account for light extinction. Using this model, we present simulated galaxy inclination distributions that account for potential selection effects.

257 – Laboratory Astrophysics Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

257.01 – Improved log(gf) Values for Lines of Ni I and New Nickel Abundances in the Sun and the Metal-Poor Star HD 84937

James E. Lawler[1], Michael P. Wood[1], Chris Sneden[2], John J. Cowan[3]
1. University of Wisconsin, Madison, WI, United States. 2. University of Texas, Austin, TX, United States. 3. University of Oklahoma, Norman, OK, United States.

New atomic transition probability measurements for 371 lines of Ni I in the UV through near IR are reported. These results are used to determine the Ni abundance of the Sun and a very metal-poor main-sequence turnoff dwarf star over a range of wavelength and E. P. values to search for non-LTE effects. For reasons only partially understood, strong lines of Ni I are unusually prone to optical depth errors in emission studies on laboratory sources. Branching fractions from data recorded using a Fourier transform spectrometer (FTS) and a 3 m echelle spectrometer are combined with published radiative lifetimes from laser induced fluorescence measurements to determine these new transition probabilities. The large echelle spectrometer provides essential UV sensitivity, spectral resolution, and especially freedom from multiplex noise that is needed to eliminate optical depth errors. There is quite good agreement with earlier, but less extensive, sets of measurements by Blackwell et al. (MNRAS 1989, 236, 235) and Wickliffe & Lawler (ApJS 1997 110, 1163). The new Ni I data are applied to high resolution visible and UV spectra of the Sun and HD 84937 to derive new, more accurate nickel abundances. In the Sun we find log(eps(Ni I)) = 6.28 (sigma = 0.06, 75 lines) and in HD 84937 we find we find log(eps(Ni I)) = 3.89 (sigma = 0.09, 77 lines), yielding [Ni/Fe] = -0.08 from log(eps(Fe)) = 7.52 in the Sun and log(eps(Fe)) = 5.19 in HD 84937. The Saha balance of Ni in HD 84937 is confirmed using 8 lines of Ni II, although these UV ion lines are somewhat saturated. This work is supported by NASA grant NNX10AN93G (JEL) and NSF grants AST-0908978 and AST-1211585 (CS).

257.02 – Updates to the CHIANTI atomic database

Peter R. Young[1], Kenneth P. Dere[1], Enrico Landi[3], Giulio Del Zanna[2], Helen Mason[2]
1. George Mason University, Washington, DC, United States. 2. University of Cambridge, Cambridge, United Kingdom. 3. University of Michigan, Ann Arbor, MI, United States.

CHIANTI is an atomic data and software package for modeling emission lines in astrophysical spectra. It is widely used in astronomy and solar physics, with over 1800 citations since 1996, and the atomic data are used by other plasma codes such as CLOUDY, APED, XSTAR and MOCASSIN. Version 7.1 of CHIANTI was released in 2012 (Landi et al. 2013, ApJ, 763, 86), and this presentation will describe changes and additions to the database for version 8 and beyond. (1) The data files will be re-formatted to allow ion models with 1000's of levels. This allows the latest atomic models for iron ions to be incorporated into the database. (2) The method for assessing and storing electron collision data will be modified to facilitate the inclusion of large atomic models. (3) Density dependent ionization balance calculations will be incorporated by modeling level-resolved recombination and recombination, and the suppression of dielectronic recombination at high densities (Nikolic et al. 2013, ApJ, 768, 82). (4) The inclusion of level-resolved recombination rates to better model X-ray lines from He and Li-like ions. (5) Improved or new atomic data for neutral, singly- and doubly-ionized species of astrophysical importance

258 – Observatory Site Protection Poster Session

Poster Session – Exhibit Hall ABC – 07 Jan 2014 09:00 am to 06:30 pm

258.01 – Spectral and Illuminance Assessment of Tucson, Arizona Light Pollution Hot Spots

Jeanine Chmielewski[1], Stephen M. Pompea[2]

1. Michigan Technological University, Houghton, MI, United States. 2. National Optical Astronomy Observatory, Tucson, AZ, United States.

Panoramic photos of Tucson taken from the top of Tumamoc Hill just west of Tucson were used to provide an overview of Tucson street lighting and to identify areas and specific luminaries that contribute to sky glow. These target areas with poor quality lighting were studied to identify specific problems such as poor shielding or over-illumination. Ten locations in Tucson along the main streets of Grant, Speedway, and Broadway were studied. The luminance emittance was measured and visible spectra were taken at these locations. The dominant light type seen at these locations was high-pressure sodium. The majority of these locations had businesses that had very high luminance emittance levels—some in excess of 700 lux, the light level recommended for a surgery preparation room. LED lights were also observed on the main campus of the University of Arizona. These lights had strong blue emission, which was generally wasted light because of the response curve of the human eye. Chmielewski was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program (AST-1262829).

258.02 – Characterizing and Quantifying Time Dependent Night Sky Brightness In and Around Tucson, Arizona

Rachel Nydegger[2, 1]

1. National Optical Astronomy Observatory, Tucson, AZ, United States. 2. Utah State University, Logan, UT, United States.

As part of a Research Experience for Undergraduates (REU) program with the National Optical Astronomy Observatory (NOAO), I (with mentor Dr. Constance Walker of NOAO) characterized light pollution in and near Tucson, Arizona using eight Sky Quality Meters (SQMs). In order to analyze the data in a consistent way for comparison, we created a standard procedure for reduction and analysis using python and MATLAB. The series of python scripts remove faulty data and examine specifically anthropogenic light pollution by excluding contributions made by the sun, moon, and the Milky Way. We then use MATLAB codes to illustrate how the light pollution changes in relation to time, distance from the city, and airglow. Data are then analyzed by a recently developed sky brightness model created by Dan Duriscoe of the National Park Service. To quantify the measurements taken by SQMs, we tested the wavelength sensitivity of the devices used for the data collection. The findings from the laboratory testing have prompted innovations for the SQMs as well as given a sense of how data gathered by these devices should be treated.

201 – AAS Prize Presentations: Education Prize, Joseph Weber Award presented by AAS President David Helfand

Plenary Session – Potomac Ballroom A – 07 Jan 2014 09:20 am to 09:40 am

202 – Instrumentation III: Ground or Airborne Missions

Oral Session – Maryland 2 – 07 Jan 2014 10:00 am to 11:30 am

202.01D – Imaging and Modeling Nearby Stellar Systems through Infrared Interferometers

Xiao Che[1], John D. Monnier[1], Theo Ten Brummelaar[2], Laszlo Sturmann[2], Rafael Millan-Gabet[3], Fabien Baron[4], Stefan Kraus[5], Ming Zhao[6]

1. University of Michigan, Ann Arbor, MI, United States. 2. The CHARA Array, Mountain Wilson, CA, United States. 3. Caltech, Pasadena, CA, United States. 4. Georgia State University, Atlanta, GA, United States. 5. University of Exeter, Exeter, United Kingdom. 6. Penn State University, University Park, PA, United States.

Contributing teams: CHARA

Long-baseline infrared interferometers with sub-milliarcsecond angular resolution can now resolve photospheric features and the circumstellar environments of nearby massive stars. Closure phase measurements have made model-independent imaging possible. During the thesis, I have expanded Michigan Infrared Combiner (MIRC) from a 4-beam combiner to a 6-beam combiner to improve the (u,v) coverage, and installed Photometric Channels system to reduce the RMS of data by a factor of 3. I am also in charge of the Wavefront Sensor of the CHARA Adaptive Optics project to increase the sensitivity of the telescope array to enlarge the observable Young Stellar Objects (YSOs). My scientific research has focused on using mainly MIRC at CHARA to model and image rapidly rotating stars. The results are crucial for testing the next generation of stellar models that incorporate evolution of internal angular momentum. Observations of Be stars with MIRC have resolved the innermost parts of the disks, allowing us to study the evolution of the disks and star-disk interactions. I have also adopted a semi-analytical disk model to constrain Mid-InfraRed (MIR) disks of YSOs using interferometric and spectroscopic data.

202.02 – Progress in the expansion of the Navy Precision Optical Interferometer

J. T. Armstrong[1], Sergio R. Restaino[1], James. H. Clark[1], Henrique R. Schmitt[1], Ellyn K. Baines[1], Donald J. Hutter[2], James A. Benson[2], Robert T. Zavala[2], Paul D. Shankland[2], Gerard van Belle[3], Anders M. Jorgensen[4]

1. NRL, Washington, DC, United States. 2. USNO, Flagstaff, AZ, United States. 3. Lowell Observatory, Flagstaff, AZ, United States. 4. New Mexico Tech, Socorro, NM, United States.

Over the past three years, the Navy Precision Optical Interferometer (NPOI) has been undergoing significant expansion toward its ultimate design goal of six siderostats that can be moved among up to 30 stations. The additional stations that will become available by next spring include E7 (98 m baseline with W7), plus E10 and W10 (432 m baseline between them). Several other close-in stations will produce baselines as short as 7 m tailored to large-scale targets. Significant upgrades to the NPOI backend are also under way. The VISION beam combiner, based on single-mode fiber spatial filtering and a photon-counting CCD and very similar in design to the MIRC combiner at the CHARA array, has been installed and is on its shakedown cruise. The NPOI's current "Classic" combiner is undergoing firmware improvements that will increase both the spectral range and the number of baselines simultaneously available. Coupled with concurrent improvements to the delay line controllers, these developments should significantly increase data quality and instrumental efficiency. Finally, many of the the initial preparations for adding four 1.8 m telescopes (the former Keck outrigger telescopes, now owned by USNO) have been completed, and funding for the first installations is anticipated.

202.03 – Improving the Visibility Amplitude Calibration of the NPOI with Photometric Information

Henrique R. Schmitt[1], David Mozurkewich[2], J. T. Armstrong[1], James A. Benson[3], Anders M. Jorgensen[4], Ellyn K. Baines[1]

1. Naval Research Laboratory, Washington, DC, United States. 2. Seabrook Engineering, Seabrook, MD, United States. 3. US Naval Observatory, Flagstaff, AZ, United States. 4. New Mexico Tech, Socoroo, NM, United States.

Atmospheric fluctuations and flux imbalance between different telescopes are issues that can limit the precision one can achieve in the calibration of optical interferometric observations. We will present results of a study done with the NPOI, where we use photometric information from the Narrow Angle Tracker as a surrogate for photometric channels. We will discuss the method and the effects of this correction on the precision of the final precision of the visibility amplitude calibration.

202.04D – Development and Commissioning of the Integral Field Spectrograph for the Gemini Planet Imager

Jeffrey K. Chilcote[1], James E. Larkin[1]
1. UC Los Angeles, Los Angeles, CA, United States.
Contributing teams: Gemini Planet Imager instrument and science teams

The Gemini Planet Imager (GPI) is one of a new generation of instruments being built to directly image extrasolar planets in the outer solar systems of young main sequence stars. By combining a 1700-actuactor adaptive optics system, an apodized-pupil Lyot coronagraph, a precision interferometric infrared wavefront sensor, and an integral field spectrograph (IFS), GPI's goal is more than an order of magnitude improvement in contrast compared to existing high contrast systems. This presentation focuses on the performance and characterization of the GPI IFS which is based on concepts from the OSIRIS instrument employed at Keck. Like OSIRIS, the IFS utilizes an infrared transmissive lenslet array to sample an approximate 2.7 x 2.7 arcsecond field of view at the diffraction limit of the Gemini Telescopes. The IFS provides over 36,000 simultaneous low-resolution (R ~ 45) spectra across five bands between 1 and 2.5µm. Alternatively, the dispersing element can be replaced with a Wollaston prism to provide broadband polarimetry of the same five filter bands. The IFS construction was based at the University of California, Los Angeles in collaboration with the Université de Montreal, Immervision and Lawrence Livermore National Laboratory. The IFS was integrated with the other components of GPI in the fall of 2011. GPI has recently finished Integration & Testing at the University of California, Santa Cruz, and has been shipped to Gemini South where it is undergoing post delivery acceptance testing.

202.05 – Simulation and Laboratory results of the Hard X-ray Polarimeter: X-Calibur

Qingzhen Guo[1], Matthias Beilicke[1], Fabian Kislat[1], Henric Krawczynski[1]
1. Washington University in Saint Louis, Saint Louis, MO, United States.

X-ray polarimetry promises to give qualitatively new information about high-energy sources, such as binary black hole (BH) systems, Microquasars, active galactic nuclei (AGN), GRBs, etc. We designed, built and tested a hard X-ray polarimeter 'X-Calibur' to be flown in the focal plane of the InFOCuS grazing incidence hard X-ray telescope in 2014. X-Calibur combines a low-Z Compton scatterer with a CZT detector assembly to measure the polarization of 20- 80 keV X-rays making use of the fact that polarized photons Compton scatter preferentially perpendicular to the E field orientation. X-Calibur achieves a high detection efficiency of order unity. We optimized of the design of the instrument based on Monte Carlo simulations of polarized and unpolarized X-ray beams and of the most important background components. We have calibrated and tested X-Calibur extensively in the laboratory at Washington University and at the Cornell High-Energy Synchrotron Source (CHESS). Measurements using the highly polarized synchrotron beam at CHESS confirm the polarization sensitivity of the instrument. In this talk we report on the optimization of the design of the instrument based on Monte Carlo simulations, as well as results of laboratory calibration measurements characterizing the performance of the instrument.

202.06 – Low-Cost InGaAs Detectors for Near-Infrared Imaging and Photometry

Peter Sullivan[1], Bryce Croll[1], Robert A. Simcoe[1]
1. Massachusetts Institute of Technology, Cambridge, MA, United States.

Near-infrared detectors made from InGaAs should provide an alternative to HgCdTe that is particularly cost-effective for arrays of small telescopes or for covering large focal planes. Originally designed for night-vision equipment, these detectors can be suitable for astronomy if they support long, up-the-ramp exposures and are cooled sufficiently. We developed custom electronics to operate the FLIR APS640C detector in a camera with thermoelectric and chilled-water cooling. We achieved differential photometric precision of 500 ppm (0.5 mmag) hr^-1/2 observing J=7.7 stars with an effective telescope aperture of 0.25 m. Laboratory results from the latest generation of InGaAs detectors will be presented, and we discuss the limits to achieving background-limited performance in the Y, J, and H bands on 1 m - class telescopes.

203 – Building the Astronomical Information Sciences: From NASA's AISR Program to the New AAS Working Group on Astroinformatics and Astrostatistics

Special Session – National Harbor 4 – 07 Jan 2014 10:00 am to 11:30 am

Do you rely on the ADS database for literature research and citation management? Do you use SAOImage DS9 to visualize astronomical images and other data? Do you access data using Virtual Observatory (VO) tools and protocols? Does your research rely on new statistical, machine learning, or data mining methods? If you answered "yes" to any of these questions, then you are benefiting from research in the astronomical information sciences. This session will begin with a retrospective look at projects funded by NASA's Applied Information Systems Research (AISR) Program that laid groundwork for this emerging area of interdisciplinary research; it will culminate with an introduction to the new AAS Working Group on Astroinformatics and Astrostatistics (AIAS), including overviews of current research in AIAS. The AISR program, led by NASA Senior Science Program Executive Joseph Bredekamp, operated from 1991 to 2012. It supported research tying together new developments in information sciences (high-performance computing, statistics, machine learning, data mining, etc.) and scientific concerns across all of NASA's science divisions: Astrophysics, Planetary Science, Heliophysics, and Earth Science. Presentations in this session will cover the history, status, and future of AISR-funded research on tools and methods for accessing, visualizing, and analyzing astronomy data across diverse applications and dataset scales. Topics to be covered include: ADS, SAOImage DS9, VAO resources, and various AIAS methods and software. The session will end with an introduction to the activities of the new Working Group on AIAS, charged by the AAS to develop and spread awareness of the applications of advanced information science tools and methods to further the goals of astronomical and astrophysical research. This will include brief overviews of several current AIAS research projects. A companion poster session will provide more detail on current AIAS research.

203.01 – Conflict and Reconciliation in Software Design

Eric Mandel[1]
1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

Data analysis software is as open-ended and complex as the research it supports. The written specification is never the full story in an arena where users can't always know what they want to do next. Requirements often are too vague or too concrete, missing or implicit. They sometimes conflict with one another. How can we design high quality software amidst these variables? In this talk, I will discuss provisional conclusions I have reached concerning software design, based on thirty years of experience developing astronomical software.

203.02 – From AISR to the Virtual Observatory

Alexander S. Szalay[1]
1. Johns Hopkins Univ., Baltimore, MD, United States.

The talk will provide a retrospective on important results enabled by the NASA AISR program. The program had a unique approach to funding research at the intersection of astrophysics, applied computer science and statistics. It had an interdisciplinary angle, encouraged high risk, high return projects. Without this program the Virtual Observatory would have never been started. During its existence the program has funded some of the most innovative applied computer science projects in astrophysics.

203.03 – Astrostatistics in X-ray Astronomy: Systematics and Calibration

Aneta Siemiginowska[1]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.
Contributing teams: Vinay Kashyap, CHASC

Astrostatistics has been emerging as a new field in X-ray and gamma-ray astronomy, driven by the analysis challenges arising from data collected by high performance missions since the beginning of this century. The development and implementation of new analysis methods and techniques requires a close collaboration between astronomers and statisticians, and requires support from a reliable and continuous funding source. The NASA AISR program was one such, and played a crucial part in our work. Our group (CHASC; http://heawww.harvard.edu/AstroStat/), composed of a mixture of high energy astrophysicists and statisticians, was formed ~15 years ago to address specific issues related to Chandra X-ray Observatory data (Siemiginowska et al. 1997) and was initially fully supported by Chandra. We have developed several statistical methods that have laid the foundation for extensive application of Bayesian methodologies to Poisson data in high-energy astrophysics. I will describe one such project, on dealing with systematic uncertainties (Lee et al. 2011, ApJ), and present the implementation of the method in Sherpa, the CIAO modeling and fitting application. This algorithm propagates systematic uncertainties in instrumental responses (e.g., ARFs) through the Sherpa spectral modeling chain to obtain realistic error bars on model parameters when the data quality is high. Recent developments include the ability to narrow the space of allowed calibration and obtain better parameter estimates as well as tighter error bars. Acknowledgements: This research is funded in part by NASA contract NAS8-03060. References: Lee, H., Kashyap, V.L., van Dyk, D.A., et al. 2011, ApJ, 731, 126

Siemiginowska, A., Elvis, M., Connors, A., et al. 1997, Statistical Challenges in Modern Astronomy II, 241

203.04 – Hyperspectral Image Analysis in Planetary Science and Astronomy

Erzsebet Merenyi[1]

1. Rice Univ., Houston, TX, United States.

Hyperspectral images (spectral signatures acquired in hundreds of narrow, contiguous band passes on a regular spatial grid over a target area) have long been utilized in planetary astronomy for remote geochemical analyses. Typical hyperspectral imagery spans the visible to near-and-thermal-infrared wavelengths with 5-20 nm ($\lambda/?\lambda > 100$) resolution, sufficient to resolve the discriminating spectral features of (near-)surface compounds. Compared with broad-band, multi-spectral imagery, hyperspectral data brings a phase change in the complexity of spectral patterns and the cluster structure and richness of the data space, and consequently in the analysis challenges for tasks like clustering, classification, regression, and parameter inference. Many traditional favorite techniques do not meet these challenges if one's aim is to fully exploit the rich, intricate information captured by the sensor, ensure discovery of surprising small anomalies, and more. In stellar astronomy, where Ångström resolution is typical, the data complexity can grow even higher. With the advent of 21st century observatories such as ALMA, high spatial and spectral resolution image cubes with thousands of bands are extending into new and wider wavelength domains, adding impetus to develop and deploy increasingly powerful and efficient knowledge extraction techniques. In this talk I will highlight applications of brain-like machine learning, specifically advanced forms of neural maps that mimic analogous behaviors in natural neural maps in brains (for example, preferential attention to rare signals, to enhance discovery of small clusters). I will present examples of information extraction from hyperspectral data in planetary astronomy, and point out advantages over more traditional techniques, for "precision" data mining, discovery of small anomalies in the face of highly irregular cluster structure, accurate inference of non-linearly entangled latent parameters, or non-linear dimension reduction. These works were done in close collaboration with colleagues in planetary science and astronomy, supported in part by the Applied Information Systems Research Program.

203.05 – Reflections on the AISR Program

Joseph Bredekamp[1]

1. NASA HQ (Ret.), Washington, DC, United States.

NASA's Applied Information Systems Research Program was an interdisciplinary research program fostering collaborations across disciplines to apply advances in information science and technology to enhance effectiveness of science research endeavors. It was initiated in 1990 and covered a broad range of topical areas, including high-performance computing and networking, data management and analysis, computational methods and algorithms, statistical tools, machine learning, etc. The AISR legacy includes foundational pieces leading to distributed science data observatory capabilities, as well as advanced computational data analysis tools and techniques which have extended the state-of-the practice in those endeavors.

203.06 – Introducing the AAS Working Group on Astroinformatics and Astrostatistics

Zeljko Ivezic[1]

1. Univ. of Washington, Seattle, WA, United States.

In response to two White Papers submitted to the Astro2010 Decadal Survey (1,2), a new AAS Working Group on Astroinformatics and Astrostatistics (WGAA) has been approved by the AAS Council at the 220th Meeting, June 2012, in Anchorage. The motivation for this WG is the growing importance of the interface between astronomy and various branches of applied mathematics, computer science and the emerging field of data science. With the new data-intensive projects envisioned for the coming decade, the need for advice derived from the focused attention of a group of AAS members who work in these areas is bound to increase. The Working Group is charged with spreading awareness of rapidly advancing computational techniques, sophsticated statistical methods, and highly capble software to further the goals of astronomical and astrophysical research. The three main strategic goals adopted by the WGAA Steering Committee for the next few years are to: (i) develop, organize and maintain methodological resources (such as software tools, papers, books, and lectures); (ii) enhance human resources (such as foster the creation of career paths, establish a Speakers' Bureau, establish and maintain an archived discussion forum, enable periodic news distribution); and (iii) organize topical meetings. The WGAA Steering Committee at this time includes twelve members: Kirk Borne, George Djorgovski, Eric Feigelson, Eric Ford, Alyssa Goodman, Joe Hilbe, Zeljko Ivezic (chair), Ashish Mahabal, Aneta Siemiginowska, Alex Szalay, Rick White, and Padma Yanamandra-Fisher. I will summarize our accomplishments since July 2012. (1) Astroinformatics: A 21st Century Approach to Astronomy (Borne & 90 coauthors), (2) The Astronomical Information Sciences: A Keystone for 21st-Century Astronomy (Loredo & 72 coauthors)

204 – Cosmology & CMB III
Oral Session – Maryland Ballroom C – 07 Jan 2014 10:00 am to 11:30 am

204.01D – SPTpol: A Cosmic Microwave Background Polarization Experiment on the South Pole Telescope

Jason Henning[1]
1. University of Colorado at Boulder, Boulder, CO, United States.
Contributing teams: SPTpol Collaboration

SPTpol is a millimeter-wavelength polarization-sensitive receiver installed on the South Pole Telescope, and it completed its second season of observations of Cosmic Microwave Background (CMB) temperature and polarization anisotropies in the fall of 2013. The receiver contains 588 dual polarization pixels at 150 GHz and 180 at 90 GHz, comprising a total of 1536 transition edge sensor bolometers. In its first year, SPTpol mapped 100 $\deg^2$ to a depth of ~ 7 and 10 μK-arcmin at 150 GHz in temperature and polarization, respectively. With this "deep-field" map, the SPTpol collaboration produced the first statistically significant detection (7.7 ?) of lensing B modes, which are produced by gravitational lensing of the E-mode CMB polarization generated at the surface of last scattering. Additionally, the full SPTpol survey just completed the first of three years mapping 500 $\deg^2$ of the southern sky. Data from the full survey will constrain the sum of the masses of neutrino species through their effect on gravitational lensing B modes. High signal-to-noise measurements of the E-mode damping tail from the full-field survey will also further constrain cosmological parameters and extensions to the concordance λCDM cosmological model. In this presentation, I will discuss preliminary results and forecasts on cosmological constraints from the full SPTpol data set.

204.02 – Exploring the Epoch of Reionization with the South Pole Telescope

Christian L. Reichardt[1]
1. UC Berkeley, Berkeley, CA, United States.
Contributing teams: SPT collaboration

The patchwork pattern of ionized and neutral bubbles created during cosmic reionization induces fine-scale temperature anisotropies in the cosmic microwave background via the kinetic Sunyaev-Zel'dovich (SZ) effect. The shape of the kinetic SZ power spectrum depends on the typical bubble sizes, while the amplitude depends on the duration of reionization. I will present new measurements of the kinetic SZ power spectrum using the full SPT-SZ survey in combination with Herschel/SPIRE data. I will then discuss the implications of these measurements for the epoch of reionization.

204.03 – Recent Results from the Atacama Cosmology Telescope

David N. Spergel[1]
1. Princeton Univ. Obs., Princeton, NJ, United States.

The Atacama Cosmology Telescope surveyed the sky at 145, 220 and 280 GHz detect primordial CMB fluctuations, dusty galaxies, radio sources and massive clusters. In 2013, we added the ACTPOL camera, a polarization sensitive camera, that is now mapping the sky with higher sensitivity. This presentation will describe recent results

204.04 – The Atacama B-Mode Search

Jonathan L. Sievers[1]
1. University of KwaZulu-Natal, Durban, South Africa.
Contributing teams: ABS Collaboration

The Atacama B-mode Search (ABS) is searching for the signature of gravity waves from inflation by observing the Cosmic Microwave Background (CMB) on large scales from the Chilean Atacama. ABS is unique amongst ground-based CMB experiments in that it has a rotating half-wave plate (HWP). The HWP modulates the polarization signal seen by the detectors at 10 Hz. The demodulated time streams are remarkably stable, with 1/f knees in the mHz range. We present preliminary results from ABS.

204.05 – Measuring the Thermal Sunyaev-Zel'dovich Effect Through the Cross Correlation of Planck and WMAP with ROSAT

Nicholas Battaglia[1], Amir Hajian[2], David N. Spergel[3], John R. Bond[2], Christoph Pfrommer[4], Jonathan Sievers[5, 3]
1. Carnegie Mellon University, Pittsburgh, PA, United States. 2. CITA, Toronto, ON, Canada. 3.

Princeton, Princeton, NJ, United States. 4. HITS, Heidelberg, Germany. 5. UKZN, Durban, South Africa.

We measure a significant correlation between the thermal Sunyaev-Zel'dovich effect in the Planck and WMAP maps and an X-ray cluster map based on ROSAT. Our measurement yields a direct characterization of the cluster power spectrum over a wide range of angular scales that is consistent with large cosmological simulations. We check for contamination from dusty galaxies using the cross correlations with the 220, 545 and 843 GHz maps from Planck. The amplitude of this signal depends on cosmological parameters that determine the growth of structure (σ_8 and Ω_M) and scales as $\sigma_8^{7.4}$ and $\Omega_M^{1.9}$ around the multipole (ell) ~ 1000. We constrain σ_8 and Ω_M from the cross-power spectrum to be $\sigma_8 (\Omega_M/0.30)^{0.26} = 0.8$ +/- 0.02. In principle this analysis can be extended beyond σ_8 and Ω_M to constrain dark energy or the sum of the neutrino masses.

204.06 – POLARBEAR2: A new multichroic receiver for precision measurements of cosmic microwave background polarization

Darcy Barron[1]
1. UC San Diego, La Jolla, CA, United States.
Contributing teams: POLARBEAR Collaboration

POLARBEAR-2 is a new receiver that will be installed in 2014 alongside the currently observing POLARBEAR-1 receiver, on a new telescope as a part of the Simons Array. The science goals of the POLARBEAR project are to do a deep search for B-mode polarization of the cosmic microwave background (CMB) created by inflationary gravitational waves, as well as characterize the CMB B-mode signal at smaller angular scales, where it originates from weak gravitational lensing. The Simons Array will include a total of three off-axis Gregorian telescopes with 3.5 m primary mirrors, located in the Chajnantor Astronomical Park in the Atacama Desert in Chile. Phased upgrades to receiver technology will enable us to improve sensitivity and capabilities, while continuing a deep survey of 80% of the sky. The POLARBEAR-2 receiver has a larger area focal plane with new dichroic pixels, with bands at 95 GHz and 150 GHz, and a total of 7,588 polarization sensitive antenna-coupled transition edge sensor bolometers. The focal plane is cooled to 250 milliKelvin, and the bolometers will be read-out by SQUID amplifiers with 32x frequency domain multiplexing. The focal plane is designed to have a noise equivalent temperature of 5.7 µK√s.

205 – Evolution of Galaxy Structure
Oral Session – Potomac Ballroom A – 07 Jan 2014 10:00 am to 11:30 am

205.01D – Galaxy Zoo: Observing Secular Evolution Through Bars

Edmond Cheung[1], Lia Athanassoula[2], Karen Masters[3], Sandra M. Faber[1], David C. Koo[1]
1. University of California Santa Cruz, Santa Cruz, CA, United States. 2. Aix-Marseille Universite, Marseille, France. 3. University of Portsmouth, Portsmouth, United Kingdom.
Contributing teams: Galaxy Zoo

In this talk, I use the Galaxy Zoo 2 dataset to study the behavior of bars in disk galaxies as a function of specific star formation rate (SSFR), and inner galactic structure, i.e., the prominence of the bulge as parameterized by Sérsic index and central surface stellar mass density. Our sample consists of 13,295 disk galaxies, with an overall bar fraction of 23.6 ± 0.4%, of which 1,154 barred galaxies also have bar length measurements. These samples are the largest ever used to study the role of bars in disk galaxy evolution. I find that the likelihood of a galaxy hosting a bar is anti-correlated with SSFR, regardless of stellar mass or bulge prominence. I find that the trends of bar likelihood with bulge prominence are bimodal with SSFR, i.e., in star-forming galaxies, bulges are more prominent in galaxies more likely to host bars, while in quiescent disk galaxies, bars are less frequent where there are prominent bulges. Our observations of bar length reveal a complex picture. In star-forming disks, longer bars are found where the bulges are more prominent, while in quiescent disks there is a maximum in the average bar length as a function of bulge prominence. I interpret these observations using state-of-the-art simulations of bar evolution which include live halos and the effects of gas and star formation. I suggest our observed trends of bar likelihood with SSFR are driven by the gas fraction of the disks; a factor demonstrated to significantly retard both bar formation and evolution in models. I interpret the bimodal relationship between bulge prominence and bar properties as due to the complicated effects of classical bulges and central mass concentrations on bar evolution, and also to the growth of disky pseudobulges by bar evolution. These results represent empirical evidence for secular evolution driven by bars in disk galaxies. This work suggests that bars are not stagnant structures within disk galaxies, but are a critical evolutionary driver of their host galaxies in the local universe (z < 1).

205.02 – Using Bars in S4G and COSMOS to Identify the Fastest Evolving Galaxy Disks at All Epochs.

Kartik Sheth[1]
1. NRAO, Charlottesville, VA, United States.
Contributing teams: S4G team

The steeply declining bar fraction from 65\% in the local Universe to $<$20\% 7 Gyr ago allowed us to constrain the detailed mass assembly of disk galaxies from the COSMOS survey. We showed that the most massive galaxies formed their bars first and by z$\sim$1, $>$50\% of massive disks already had bars. The low mass galaxies evolved to acquire their bars only very recently. Now using the Spitzer Survey of Stellar Structure in Galaxies (S4G) we show that this mass-dependent trend is extremely clear in the 2300+ galaxy sample. Galaxies with masses log M $>$ 9.5 have bar fractions of 65\% whereas galaxies masses log M $<$ 9 have almost no bars -- in direct contrast to other studies that have claimed an increase in bars at the low mass end. We show that elongations due to poor quality imaging and blurring of nearby star forming regions likely lead to a mis-classification of bars in late type, low mass galaxies. At log M $\sim$9.2 there is a increase in the bar fraction indicating that the bar formation is occurring at the fastest rate in these systems - that is now the epoch of mature disk building.

205.03D – Structural Properties of Barred Galaxies

Taehyun Kim[1, 2], Dimitri A. Gadotti[3], Kartik Sheth[4], Myung Gyoon Lee[1]
1. Seoul National University, Seoul, Korea, Republic of. 2. Carnegie Observatories, Pasadena, CA, United States. 3. ESO, Santiago, Chile. 4. NRAO, Charlottesville, VA, United States.
Contributing teams: S4G Team

We have performed two-dimensional multicomponent decomposition of 144 local barred spiral galaxies using 3.6 micron images from the Spitzer Survey of Stellar Structure in Galaxies. Our model fit includes up to four components (bulge, disk, bar, and a point source) and, most importantly, takes into account disk breaks. We present that ignoring the disk break and using a single disk scale length in the model fit for Type II (down- bending) disk galaxies can lead to differences of 40% in the disk scale length, 10% in bulge-to-total luminosity ratio (B/T), and 25% in bar-to-total luminosity ratios. We show that for galaxies with B/T > 0.1, the break radius to bar radius, r_br/R_bar, varies between 1 and 3, but as a function of B/T the ratio remains roughly constant. This suggests that in bulge-dominated galaxies the disk break is likely related to the outer Lindblad Resonance (OLR) of the bar, and thus the OLR also moves outwards at the same rate as the bar grows. For galaxies with B/T < 0.1, r_br/R_bar, spans a wide range from 1 to 6. This suggests that the mechanism that produces the break in these galaxies may be different from that in galaxies with more massive bulges. Consistent with previous studies, we conclude that disk breaks in galaxies with small bulges may originate from bar resonances that may be also coupled with the

spiral arms, or be related to star formation thresholds. We quantifiy shapes of bar radial surface brightness profiles by measuring their Sersic indices and show that bars in higher B/T galaxies have flatter radial surface brightness profile than bulgeless galaxies do. In particular, bulgeless galaxies mostly have bars with steep profiles. We show that the normalized bar length is correlated with B/T, which is consistent with bars growing longer with time.

205.04 – A Characteristic Mass in the Low Redshift Tully Fisher Relation

Raymond Simons[1], Susan A. Kassin[2], Benjamin J. Weiner[3], Janice C. Lee[2, 4]
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We study the stellar mass Tully Fisher relation (TFR; rotation velocity versus stellar mass) without pre-selecting morphologies for a sample of star forming galaxies at redshifts $0.1 < z < 0.375$ from Kassin et al. (2007). Spectra are from Keck/DEIMOS (DEEP2 Survey) and images are from Hubble (AEGIS and CANDELS Surveys). In particular, we study the role morphology plays in the TFR, using qualitative and quantitative measures. Kassin et al found that the TFR at these redshifts is relatively tight for galaxies with stellar masses log $M^* > 9.5$, but has significant scatter to low rotation velocities for less massive galaxies which are disturbed/compact. We show quantitatively that the low mass galaxies log $M^* < 9.5$ which scatter from the TFR at these redshifts are compact and asymmetric. We perform a careful review of literature on the TFR at log $M^* < 9.5$ and find that the vast majority of galaxies have quantitative morphologies indicating disks. We argue that a sample without pre-selection reveals that a significant population of star forming galaxies at these masses (locally and in our relatively low redshift range) are actually compact and asymmetric with large components of disordered motions. It is unclear whether the disorder in these low redshift systems is a result of external dynamic interactions (tidal forces, merger history) or if these galaxies are in a less evolved state.

205.05 – The Wavelength Dependence of High-Redshift Galaxy Structure in the Rest-Frame Ultraviolet

Nicholas A. Bond[1], Jonathan P. Gardner[1], Duilia F. De Mello[2], Harry I. Teplitz[3], Marc Rafelski[3], Anton M. Koekemoer[4], Dan A. Coe[4]
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We present rest-frame UV morphological results for a sample of 198 star-forming galaxies at $0.5 < z < 1.5$ and perform a differential morphology analysis with respect to rest-frame optical imaging taken with ACS and WFC3. We find a ~5% decrease in effective radius in the far UV relative to 3000 Angstroms and a decrease in concentration of ~0.05. While the wavelength dependence of size is independent of rest-UV size at all redshifts, concentration decreases more sharply in the FUV for large galaxies at z~1, primarily due to the presence of UV-red bulges at the galaxy center. This size-dependent decrease in concentration is less dramatic at z~2, suggesting that bulges are less dusty, younger, and/or less massive. In addition, we show resolved $m_{1500} - m_{3000}$ color maps of 34 galaxies with spectroscopic redshifts. Outside of the central bulge, individual galaxies show little scatter in FUV color, which is consistent with a with a model in which the FUV is primarily tracing short-lived, clumpy star-formation

205.06 – On the Reliability of Structural Parameters for Compact, High-redshift Galaxies

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Rest-frame optical observation of galaxies at z~2 have revealed a high fraction of quiescent massive galaxies at this redshift. Their extremely compact nature compared to local massive galaxies have been the subject of considerable discussion. The early formation and subsequent evolution of these objects present a challenge to current models of galaxy formation and evolution. The rarity of these compact massive galaxies at low-z implies considerable size evolution between z=2 and z=0. We devise realistic simulations to systematically disentangle effects due to the technique (specifically using GALFIT) and the intrinsic structures of the galaxies. By accurately capturing the detailed structures of nearby elliptical galaxies and relocating them out to z=2, we confirm that the massive quiescent galaxies at z~2, the so-called "Red Nuggets", are significantly more compact than early-type galaxies of similar masses today. Their observed compactness is not a result of missing the faint outer part of the galaxy due to systematic errors in modeling. In fact, we find that fitting multi-component galaxies with a single Sersic profile has at most 10-20% bias toward larger sizes, which accentuates the amount of size evolution required. In

addition to the basic question of how these compact high-z galaxies evolve in size, there is also still much debate about how these massive galaxies evolve in terms of their fundamental morphological type. Several studies have shown that a significant fraction of "Red Nuggets" are disk-dominated. The small size of these galaxies can make the determination of B/T challenging. By employing the robust scaling relations and constrains found by studies on bulge+disk galaxies, we simulate disky galaxies with a wide ranges of bulge and disk sizes, B/T, and S/N. We then test the reliability of our decomposition method by retrieving the properties of each component, and B/T of the simulated galaxies. Furthermore, The effective radius of the "Red Nuggets" are comparable to and in some cases smaller than the PSF FWHM. Therefore, one may expect some offset in GALFIT measurements when an inaccurate PSF is used. This effect is studied by using inaccurate PSF models for modeling the simulated galaxies.

205.07 – The SAMI Galaxy Survey: One Year, 50000 Spectra

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Contributing teams: The SAMI Galaxy Survey team

Less than a year into its operations on the Anglo-Australian Telescope, the SAMI Galaxy Survey has collected spatially resolved (IFU) spectroscopy of 440 galaxies. This breaks all previous records owing to the novel 13-fold multiplexing of the newly-designed, lightly-fused 'hexabundles' of 61 optical fibre cores that can be deployed over a degree-wide field. (Illustrations can be found in the partner poster presentation by Gerald Cecil and at http://sami-survey.org.) On our way toward the completion of a ~3000-galaxy-strong sample, that is, of order $4\text{x}10^5$ full-optical spectra, we are working on the key scientific objectives of: (i) Mapping the mechanisms that advance and suppress the star formation process and induce morphological transformation in a variety of environments; (ii) Surveying the frequency of gas flows into and out of galaxies of all masses, and deducing the effect on gas phase metallicity and baryonic budgets; (iii) Recording the distribution of angular momentum across the local Universe, thereby advancing our understanding of how mass is built up over time. Our simulations team is working in parallel with the observers to produce mock SAMI data-cubes and interpret our results in a cosmological context. Furthermore, having selected most of our sample from the all-wavelength *GAMA* survey affords us access to invaluable ancillary information. The SAMI Galaxy Survey, which adds resolved stellar and gas phase kinematics, star formation rates, ionisation diagnostics, stellar ages, metallicities, and much more will provide a unique and long lasting legacy for the astronomical community.

206 – Extrasolar Planet Detection - Identification, Classification, and Validation of Kepler Candidates

Oral Session – Maryland Ballroom A – 07 Jan 2014 10:00 am to 11:30 am

206.01 – The Applicability of Emerging Quantum Computing Capabilities to Exo-Planet Research

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In conjunction with the Universities Space Research Association and Google, Inc. NASA Ames has acquired a quantum computing device built by DWAVE Systems with approximately 512 "qubits." Quantum computers have the feature that their capabilities to find solutions to problems with large numbers of variables scale linearly with the number of variables rather than exponentially with that number. These devices may have significant applicability to detection of exoplanet signals in noisy data. We have therefore explored the application of quantum computing to analyse stellar transiting exoplanet data from NASA's Kepler Mission. The analysis of the case studies was done using the DWAVE Systems's BlackBox compiler software emulator, although one dataset was run successfully on the DWAVE Systems's 512 qubit Vesuvius machine. The approach first extracts a list of candidate transits from the photometric lightcurve of a given Kepler target, and then applies a quantum annealing algorithm to find periodicity matches between subsets of the candidate transit list. We examined twelve case studies and were successful in reproducing the results of the Kepler science pipeline in finding validated exoplanets, and matched the results for a pair of candidate exoplanets. We conclude that the current implementation of the algorithm is not sufficiently challenging to require a quantum computer as opposed to a conventional computer. We are developing more robust algorithms better tailored to the quantum computer and do believe that our approach has the potential to extract exoplanet transits in some cases where a conventional approach would not in Kepler data. Additionally, we believe the new quantum capabilities may have even greater relevance for new exoplanet data sets such as that contemplated for NASA's Transiting Exoplanet Survey Satellite (TESS) and other astrophysics data sets.

206.02 – Likely Planet Candidates Identified by Machine Learning Applied to Four Years of Kepler Data

Jon M. Jenkins[1], Sean D. McCauliff[2], Joseph Catanzarite[1], Joseph D. Twicken[1], Christopher J. Burke[1], Jennifer Campbell[2], Shawn Seader[1]

1. SETI Institute, Moffett Field, CA, United States. 2. Orbital Sciences Corporation, Moffett Field, CA, United States.

Over 3200 transiting planet candidates, 134 confirmed planets, and ~2,400 eclipsing binaries have been identified by the Kepler Science pipeline since launch in March 2009. Compiling the list of candidates is an intensive manual effort as over 18,000 transit-like signatures are identified for a run across 34 months. The vast majority are caused by artifacts that mimic transits. While the pipeline provides diagnostics that can reduce the initial list down to ~5,000 light curves, this effort can overlook valid planetary candidates. The large number of diagnostics (~100) makes it difficult to examine all the information available. The effort required for vetting all threshold-crossing events (TCEs) takes several months by many individuals associated with the Kepler Threshold Crossing Event Review Team (TCERT). We have developed a random-forest classifier that classifies each TCE as `planet candidate', `astrophysical false positive', or `non-transiting phenomena'. Ideally the algorithm will generate a list of candidates that approximates those generated by human review, thereby allowing the humans to focus on the most interesting cases. By using a machine learning-based auto-vetting process, we have the opportunity to identify the most important metrics and diagnostics for separating signatures of transiting planets and eclipsing binaries from instrument-induced features, thereby improving the efficiency of the manual effort. We report the results of applying a random forest classifier to four years of Kepler data. We present characteristics of the likely planet candidates identified by the auto-vetter as well as those objects classified as astrophysical false positives (eclipsing binaries and background eclipsing binaries). We examine the auto-vetter's performance through receiver operating characteristic curves for each of three classes: planet candidate, astrophysical false positive, and non-transiting phenomena. Funding for this mission is provided by NASA's Science Mission Directorate.

206.03 – Increasing the sensitivity of the Kepler legacy archive to transiting planets

Martin D. Still[1]

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All legacy light curves archived by the Kepler project are available to the community. They are based upon simple aperture extractions from time-tagged pixel data. We demonstrate that this photometry method works well for the bright end of the Kepler target sample yet there is enormous scope for further gains in sensitivity to planet transits of faint stars in the sample.

To this end, all pixel data have been made available in the archive. Methods for the user community to optimize aperture photometry and exploit point spread function modeling are being developed. Exploiting existing Kepler planet candidates, we showcase the signal-to-noise to be gained by these methods. We argue that at the faintest end of the candidate distribution, optimization provides a factor two improvement in sensitivity to transits, reaching the signal-to-noise promised by the eight year mission, curtailed by reaction wheel failure after four years. These methods can provide potentially significant improvement to a number of facets of the Kepler mission: 1. Sensitivity to new planet candidates residing currently below the signal-to-noise detection threshold; 2. Characterizing known transit profiles to higher precision; 3. Identifying contamination from nearby sources and removing contamination bias from transit depths; 4. Mitigating focus and pointing systematics within the Kepler data, and 5. Allowing the direct characterization of time-dependent physical and detector biases within the image background. With exisiting focal plane calibrations, the number of targets that currently benefit from optimized photometry is relatively small, limited to sources of magnitude Kp > 16. However, with additional refinement of the focal plane calibration, improvement in light curve quality for objects 14 < Kp < 16 can be anticipated, impacting 50% of the Kepler target sample. These methods are equally applicable to data from the upcoming TESS mission and are potentially a critical component to the exploitation of a two-wheel Kepler mission currently being developed and tendered.

206.04 – Updating the M Dwarf Planet Occurrence Rate by Injecting and Detecting Transits in Kepler Light Curves

Courtney D. Dressing[1], David Charbonneau[1]
1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

The primary goal of the Kepler mission is to constrain the occurrence rate of planets around stars with a range of spectral types. Previously, we estimated the M dwarf planet occurrence rate by revising the stellar parameters of the Kepler M dwarfs and analyzing the first six quarters of Kepler data. We found that there are 0.90 Earth-size (0.5-1.4 Earth radius) planets with periods <50 days per small star. We also found an occurrence rate of 0.15 Earth-size planets within the habitable zone per small star, implying a most probable distance of 13 pc to the nearest transiting potentially habitable planet. Our previous estimate of the occurrence rate assumed 100% detection efficiency at SNR=7.1 sigma, but the occurrence rate would have been underestimated if the actual detection efficiency is lower. In order to more accurately model the detection efficiency, we have developed a customized transit search pipeline tailored for application to M dwarfs. We measure the detection efficiency of our pipeline by injecting known transit signals into Kepler light curves and attempting to recover the signals. We are currently conducting a search for additional transiting planets using our pipeline and will compare our list of detected candidates to the candidates found by the Kepler team. We will then combine our more sophisticated model for the detection threshold and the list of planet candidates found using an additional ten quarters of Kepler data with our revised stellar parameters to present an updated measurement of the planet occurrence rate for M dwarfs. Our revised measurement will help enable predictions of the population of planets that will be detected by ongoing and future planet surveys such as MEarth and the Transiting Exoplanet Survey Satellite.

206.05 – Probabilistic Model-Based Analysis of Kepler Transit Signal Locations

Steve Bryson[1], Tim Morton[2]
1. NASA Ames Research Center, Moffett Field, CA, United States. 2. Princeton University, Princeton, NJ, United States.
Contributing teams: The Kepler Team

A dominant source of false positives in Kepler data is stellar eclipses or planetary transits on background stars. An important method of identifying these background transit signal sources is the determination of the position of the source relative to the target star. Traditionally the Kepler project has used a simple "the distance from the source to the target star is greater than 3 sigma" threshold to declare when the transit source is unlikely to be on the target star. This approach is unsatisfactory in several ways, including: 1) this simple threshold assumes that the transit signal location measurement error obeys Gaussian statistics; 2) the case of background stars within 3 sigma are not handled in an informative way; 3) the case of the transit source location measurement apparently coinciding with a known star is not handled differently from when there is no known star; 4) systematic error in the transit signal location measurement due to field crowding are not accounted for; and 5) the Galactic-latitude-dependent diffuse background source density is not accounted for. We present an alternative approach that uses forward modeling and non-parametric reconstruction of the measurement error distribution from Kepler data to address these concerns. Specifically we produce estimated distributions of both the measured transit source position and the expected transit source position under the assumption that the transit is on each known star or the diffuse background. The normalized integral of the product of the observed distribution and each star's (or background) predicted distribution gives the relative probability that the transit occurs on that star (or background). The choice of method for reconstructing the error distribution is crucial. We describe several possibilities, and recommend a smooth bootstrap reconstruction, which combines a bootstrap analysis with kernel density estimation. We describe a table giving these probabilities for KOIs that have appropriate centroid data.

206.06 – VALFAST: Secure Probabilistic Validation of Hundreds of Kepler Planet

Candidates

Tim Morton[1], Erik Petigura[2], John A. Johnson[3], Andrew Howard[4], Geoffrey W. Marcy[2], Christoph Baranec[4], Nicholas M. Law[5], Reed L. Riddle[6], David R. Ciardi[7]
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Contributing teams: Robo-AO Team

The scope, scale, and tremendous success of the Kepler mission has necessitated the rapid development of probabilistic validation as a new conceptual framework for analyzing transiting planet candidate signals. While several planet validation methods have been independently developed and presented in the literature, none has yet come close to addressing the entire Kepler survey. I present the results of applying VALFAST---a planet validation code based on the methodology described in Morton (2012)---to every Kepler Object of Interest. VALFAST is unique in its combination of detail, completeness, and speed. Using the transit light curve shape, realistic population simulations, and (optionally) diverse follow-up observations, it calculates the probability that a transit candidate signal is the result of a true transiting planet or any of a number of astrophysical false positive scenarios, all in just a few minutes on a laptop computer. In addition to efficiently validating the planetary nature of hundreds of new KOIs, this broad application of VALFAST also demonstrates its ability to reliably identify likely false positives. This extensive validation effort is also the first to incorporate data from all of the largest Kepler follow-up observing efforts: the CKS survey of ~1000 KOIs with Keck/HIRES, the Robo-AO survey of >1700 KOIs, and high-resolution images obtained through the Kepler Follow-up Observing Program. In addition to enabling the core science that the Kepler mission was designed for, this methodology will be critical to obtain statistical results from future surveys such as TESS and PLATO.

207 – Extrasolar Planet: Atmospheres

Oral Session – Maryland Ballroom B – 07 Jan 2014 10:00 am to 11:30 am

207.01D – Diamonds in the Rough: A Cautionary Tale of C/O Ratios in Exoplanet Host Stars

Johanna K. Teske[1], Katia M. Cunha[2, 1], Simon C. Schuler[3], Caitlin A. Griffith[4], Verne V. Smith[5]
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It is currently unknown how/to what extent the chemical compositions of planetary atmospheres correlate with those of their host stars and if different host star compositions influence planet occurrence. The carbon-to-oxygen abundance ratio is one crucial measurement that may be used to better understand a possible connection between star and planet compositions. In gas giant atmospheres, the C/O ratio indicates the abundances of the primary O and C species, which, along with N species, regulate the climates of Solar System planets. The composition of a planetary atmosphere affects its temperature and chemistry, and therefore its observable signatures. The C/O ratio also establishes interior mineralogy – i.e., whether the planet is Si- or C-rich. Currently C and O are the only elements that can potentially be measured in both star and exoplanet atmospheres. Large samples of planet and host star C/O measurements may reveal trends indicative of processes in the protoplanetary disk or planetary interior that shift the planet's elemental composition away from the star's. However, estimating C/O ratios in transiting exoplanet atmospheres is mostly still based on only a few photometric observations. Moreover, even with high resolution, high S/N spectra, determinations of the stellar C/O ratios can be challenging. There are only a few O abundance indicators available at optical wavelengths and they are weak, blended with other atomic/molecular lines, and/or subject to non-LTE effects. I will present a methodologically consistent sample of C/O ratios measured from high-resolution spectra of transiting exoplanet host stars from several different C and O abundance indicators, using classical stellar abundance analysis techniques (including differential, line-by-line analysis w.r.t. the Sun). I will discuss the difficulties of host star abundance measurements, and what insights into planet formation and composition are possible from such analyses. I will highlight the case of 55 Cnc, a cool and metal-rich star whose O abundance measurements are even more challenging. Our results indicate that this star is not C-rich, as previously suggested, which impacts the proposal that the super-Earth 55 Cnc e is a "diamond" planet.

207.02 – Constraints on Elemental Abundance Ratios in Hot Jupiter Atmospheres and Implications for Their Formation Conditions

Nikku Madhusudhan[1]
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Spectroscopic observations of hot Jupiters in the past few years have led to the possibility of determining elemental abundance ratios in their atmospheres. It has been demonstrated that the O/H and C/O ratios in hot Jupiters can be measured more easily than those for giant planets in the solar system where temperatures are too low for water to be accessible to spectroscopic observations. Nominal constraints on atmospheric C/O ratios have already been reported for a few hot Jupiters (Madhusudhan 2012). In the present work, we combine existing data, from the Spitzer space telescope and from ground-based facilities, with new data obtained using the Hubble space telescope to place new constraints on the C/H, O/H, and C/O ratios in five hot Jupiters. The systems considered in our study span a wide range of incident irradiation and, hence, equilibrium temperatures. We use our estimates of the elemental abundance ratios in the hot Jupiters to constrain the range of volatile compositions of their formation environments and their subsequent evolution.

207.03 – Characterizing the Atmospheres of Super-Earths and Hot-Jupiters with Narrow-Band Photometry

Knicole D. Colon[1], Eric Gaidos[2], Paul A. Wilson[3], Eric B. Ford[4], David K. Sing[3], Gilda E. Ballester[5], Jean-Michel Desert[6], David Ehrenreich[7], Jonathan J. Fortney[8], Alain Lecavelier des Etangs[7], Mercedes Lopez-Morales[9], Caroline Morley[8], Alex Pettitt[3], Frederic Pont[3], Alfred Vidal-Madjar[10]
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Nearly one thousand extrasolar planets have been discovered, but none are considered true analogs to solar system planets.

Instead, we characterize some planets as "super-Earths" or "hot-Jupiters." It has been possible to characterize the atmospheres of some of these planets via transit observations, which is a crucial stepping stone towards future studies of true solar system analogs. We present narrow-band photometry of several transiting planets, including the super-Earth GJ 1214b and the hot-Jupiters XO-2b and TrES-2b. For GJ 1214b, most studies find that the transmission spectrum is flat, which favors either a high mean molecular weight or cloudy/hazy hydrogen (H) rich atmosphere model. We observed seven transits of GJ 1214b through a narrow K-band (2.141 micron) filter with the Wide Field Camera on the 3.8 meter United Kingdom Infrared Telescope. We observed another five transits at 800-900 nm using tunable filters with the Optical System for Imaging and low Resolution Integrated Spectroscopy (OSIRIS) on the 10.4 meter Gran Telescopio Canarias (GTC). Our observations support a flat transmission spectrum for GJ 1214b, but we also find that a hydrogen-dominated upper atmosphere cannot be excluded. For hot-Jupiters, potassium has been predicted to be one of the strongest sources of opacity at optical wavelengths and has been previously detected in the atmospheres of XO-2b and TrES-2b. Using OSIRIS on the GTC, we observed three transits of XO-2b and two transits of TrES-2b in multiple bandpasses around the potassium absorption feature at 770 nm. Our technique is somewhat different than in previous studies, and we use our observations to constrain the amount of potassium in these exoplanet atmospheres. We consider how our studies set the stage for future investigations of true Earth and Jupiter analogs that have not yet been discovered.

207.04 – Significance of Trends in Exoplanetary Atmospheres

Joseph Harrington[1], M. Oliver Bowman[1], Sarah D. Blumenthal[1], Thomas J. Loredo[2]
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Contributing teams: the UCF Exoplanets Group

Cowan and Agol (2011) and we (Harrington et al. 2007, 2010, 2011, 2012, 2013) have noted that at higher equilibrium temperatures, observed exoplanet fluxes are substantially higher than even the elevated equilibrium temperature predicts. With a substantial increase in the number of atmospheric flux measurements from observatories like Spitzer, and now even from the ground, we can test the statistical significance of this trend. We can also cast the data on a variety of axes to search further for the physics behind both the jump in flux above about 2000 K and the wide scatter in fluxes at all temperatures. This work was supported by NASA Planetary Atmospheres grant NNX12AI69G and NASA Astrophysics Data Analysis Program grant NNX13AF38G.

207.05 – Exoplanet transits in X-rays: a new observational window to the exoplanetary atmosphere

Katja Poppenhaeger[1], Scott J. Wolk[1], Juergen Schmitt[2]
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Exoplanets in short-period orbits are subject to strong irradiation from their host star and can lose mass through evaporation. The main driver for this evaporation is high-energy emission from the host star. However, it is observationally unclear where in the exoplanetary atmosphere the bulk of the high-energy radiation is absorbed, and the energy budget for the evaporation is not well constrained. We have observed seven transits of the Hot Jupiter HD 189733 b in front of its host star, using X-ray observations with Chandra and XMM-Newton. We detect the exoplanetary transit in X-rays for the first time. We find a surprisingly large X-ray transit depth of 6-8%, in stark contrast to an optical transit depth of only 2.4%. We can trace this back to extended outer atmosphere layers of the planet which reach out to 1.75 optical planetary radii in altitude. We are able to derive density and temperature estimates for the outer planetary atmosphere, as well as a revised energy budget for planetary evaporation due to the large X-ray absorbing radius. These observations, together with accepted further programs in the X-ray regime, will allow us to build a comprehensive picture of the atmospheres of strongly irradiated exoplanets.

207.06 – A Survey of the Hottest Jupiter Atmospheres via Secondary Eclipses

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Secondary eclipse observations of transiting planets provide a unique way to study the chemistry and physics in their atmospheres. Constraining the atmospheric compositions of these planets could also shed light on where and how they formed, as the variation of C to O ratio in the proto-planetary disks may imprint signatures in the planetary atmospheres. The hottest Jupiter-like planets are particularly suitable for these studies due to their large radii, high temperatures, and few condensed constituents. Here we report our first results toward a coherent survey of the hottest Jupiter atmospheres using the Palomar 200in telescope and the Spitzer Space Telescope. We will also briefly introduce our novel, diffuser-assisted approach for high precision ground-based photometry of exoplanetary atmospheres.

207.07 – New Frontiers for Comparative Exoplanetology

Jean-Michel Desert[1]

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The study of the atmospheres of representative exoplanets is the next important step for constraining planetary formation and for improving our knowledge on exoplanetary physics. In this framework, the investigation of transiting planet atmospheres is a particularly important component of exoplanet characterization. This is because it is only for transiting exoplanets that we can determine masses and radii, and therefore examine their atmospheres without degeneracies. Knowledge of a planet's mass and radius together give us powerful constraints on its bulk composition, and spectroscopic studies can reveal further details about atmospheric composition (e.g., metallicity and carbon-to-oxygen ratio) and physical conditions (e.g., temperature-pressure profile, evaporation, chemistry, presence of clouds and hazes, and winds). I present cutting-edge observational programs whose purposes are to characterize planetary systems transiting nearby stars through the observations of their atmospheres. These observations reveal a wide diversity in exoplanet atmospheres, which we attempt to explain.

208 – Galaxy Clusters: Cosmology and Evolution

Oral Session – National Harbor 10 – 07 Jan 2014 10:00 am to 11:30 am

208.01 – Galaxy clusters in DES

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Contributing teams: DES Collaboration

Galaxy clusters are one of the four key cosmic acceleration probes used by the Dark Energy Survey (DES) to measure cosmological parameters with unprecedented precision. DES has recently completed commissioning of its instrument and accomplished a successful science verification data taking phase. The survey proper started in Aug 31, 2013. In this talk, I review the motivation for using clusters of galaxies in cosmology, discuss the DES expected performance and present the prospects to improve our understanding of dark energy by constraining cosmological models using galaxy clusters found by the Voronoi Tesselation galaxy cluster finding algorithm. We show results of our galaxy cluster analysis based on the early DES data sets.

208.02D – MUSTANG and MUSTANG 1.5: High-Resolution Measurements of the Sunyaev-Zel'dovich Effect in Galaxy Clusters.

Alexander Young[1], Charles Romero[2], Simon Dicker[1], Brian S. Mason[2], Tony Mroczkowski[5], Erik D. Reese[6], Craig L. Sarazin[2], Jack Sayers[3], Niclole G. Czakon[3], Mark J. Devlin[1], Phillip Korngut[3], Jonathan Sievers[4]
1. University of Pennsylvania, Philadelphia, PA, United States. 2. University of Virginia, Charlottesville, VA, United States. 3. Caltech, Pasadena, CA, United States. 4. University of Kwazulu-Natal, Durban, South Africa. 5. Naval Research Lab, Washington, DC, United States. 6. Moorpark College, Moorpark, CA, United States.

High-resolution GBT+MUSTANG observations of the Sunyaev-Zel'dovich Effect (SZE) at 90GHz have revealed complex substructure in the hot intra-cluster medium (ICM) of several massive galaxy clusters. The SZE is a nearly redshift-independent, complementary probe of the ICM to X-ray emission and combined analyses of both data sets provide a better understanding of astrophysical phenomena such as shocks, cold fronts, and sloshing of the gas within a cluster's dark matter potential. Understanding how substructure, especially in merging clusters, affects the scaling between SZE flux and total cluster mass is essential to placing tight constraints on cosmological parameters with SZE surveys. First, I will present recent results from MUSTANG observations of the SZE in MACS J0647.7+7015 and MACS J1206.2-0847. In order to better characterize the cluster dynamics, a number of models are jointly fit in the map domain using a least squares fitting routine. We compare our data to the best-fit generalized Navarro, Frenk, and White (gNFW) profiles from Bolocam and find evidence for a steeper central slope in both clusters than had previously been determined. Furthermore, MUSTANG detects significant features near the core of both clusters that are suggestive of substructure. High-resolution SZE measurements out to larger angular scales will be necessary to better understand the nature of features like these. With this in mind, we are building MUSTANG-1.5, a new bolometer camera which offers many advantages over MUSTANG and unlocks SZE's true potential as an independent tool to understand the ICM on a broad range of angular scales and with a noise level better than any current instrument. I will present a status report on the progress of the receiver, which we aim to install on the Green Bank Telescope (GBT) for first light this season. The improvement in sensitivity and much larger field-of-view (3.5' compared to 35" for MUSTANG) will enable us to pursue a far more comprehensive observing program including the first ever detection of X-ray cavities via the SZE and high-resolution measurements of the ICM out to unprecedented radii.

208.03D – Investigations of Galaxy Clusters Using Gravitational Lensing

Matthew P. Wiesner[1], Huan Lin[2], Marcelle Soares-Santos[2]
1. Northern Illinois University, Dekalb, IL, United States. 2. Fermi National Accelerator Laboratory, Batavia, IL, United States.

In this dissertation talk I describe my studies of galaxy clustering and gravitational lensing; both are important phenomena which can be used to study the structure and evolution of the universe. First I describe a sample of ten strong-lensing galaxy clusters of mass between $1\text{-}30\text{x}10^{14}$ $h^{-1}M_\text{™}$. These clusters were found in the Sloan Digital Sky Survey and were further observed using the WIYN 3.5-m telescope at Kitt Peak National Observatory and the Astrophysical Research Consortium 3.5-m telescope at Apache Point Observatory. Analyses of these clusters showed that the four lowest mass clusters in this sample exhibit overconcentration, that is, the concentration of mass in the centers of the clusters was higher than theory would predict. Second, I describe lens models of three of the strong lenses in this sample using a Bayesian algorithm for lens modeling. Finally I describe measurements of a mass-richness relation for galaxy clusters found at higher median redshift (z?0.6) than has been typical of previous sky surveys. This relation empirically describes how the mass of galaxy clusters is

related to the number of galaxies in the cluster. Mass-richness calibration is a key component of cosmology analyses using galaxy clusters; thus this work will be important to studies of cosmology done with this decade's large sky surveys. Galaxy clusters were found using a Voronoi Tessellation cluster finder and masses were measured using stacked weak lensing shear measurements in bins of similar richness. The mass-richness relation was derived using data from the Blanco Cosmology Survey and from the Sloan Digital Sky Survey Stripe 82 coadd, leading to a sample of clusters covering a total sky area of about 400 square degrees.

208.04 – A view of massive compact galaxies in nearby galaxy clusters with GeMS/GSAOI

Eleazar R. Carrasco Damele[1], Ignacio Trujillo[2]
1. Gemini Observatory, La Serena, Chile. 2. Instituto de Astrofisica de Canarias, Tenerife, Spain.

Massive galaxies at z>2 were a factor of 4 smaller than their present-day local counterparts. In the nearby universe (z<0.2), these galaxies are rare and relatively young. Recent works have suggested that nearby cluster of galaxies have significant fraction of massive compact galaxies, which are old and intriguingly, are not detected in large surveys. In this contribution we present preliminary analysis of the structural parameters of massive compact galaxies in one galaxy cluster based on high resolution, near diffraction limited images obtained with GeMS/GSAOI at Gemini South.

208.05 – Determining the Halo Mass Scale Where Gas Accretion onto Galaxies Stops

Gregory Rudnick[1, 2]
1. University of Kansas, Lawrence, KS, United States. 2. Max-Planck-Institute for Astronomy, Heidelerbg, Germany.
Contributing teams: ESO Distant Cluster Survey (EDisCS)

Despite decades of work, it is still unclear whether a galaxy's properties are affected by environment or whether they are determined solely by the galaxy's mass. I will present new results that shed light on the key question of whether galaxies have their gas supplies cut off in dense environments. Addressing this problem observationally is key as environmental processes are only primitively modeled in theoretical studies. We use a sample of homogeneously-selected massive galaxies with old stellar populations to determine in which environment gas accretion onto galaxies from the Inter-Galactic Medium (IGM) is cut off. We make significant advances with respect to previous works by probing a large number of clusters (not available in DEEP2 or COSMOS), a large number of groups, using precisely matched field samples, and using deep spectra of hundreds of cluster and field galaxies. After accounting for underlying trends with stellar mass we find that galaxies that are dominated by old stellar populations are likely to have weak emission if they are in the field while galaxies with identical stellar populations in clusters and groups have almost no activity. This activity corresponds to the heating of diffuse gas by pre-existing stellar populations. The source of the gas is both intrinsic (from stellar mass loss) and extrinsic (from accretion from the IGM). In clusters and groups, the extrinsic gas supply is cut off, implying that even group halo mass scales are effective at decoupling galaxies from the gas umbilical cords that link them to the IGM. I will discuss the evidence for additional environmental processes that affect the gas supply.

208.06 – Improved LRG Selection Algorithms combining Optical And WISE (Infrared) Photometry

Abhishek Prakash[1], Jeffrey Newman[1]
1. University of Pittsburgh, Pittsburgh, PA, United States.
Contributing teams: eBOSS collaboration

Luminous red galaxies (LRGs) are the most massive galaxies in nearby universe of z < 1.0 which appear to have formed the bulk of their stars at early times. Mostly ellipticals, they are associated with massive dark matter halos and hence cluster very strongly which makes them an excellent tracer of the large-scale structure of the Universe. LRGs at z < 0.6 can be selected efficiently using optical photometry, but at z >0.6 this becomes increasingly difficult. Here we present the results of new techniques now being applied to select LRGs at redshifts 0.6 < z < 1 utilizing SDSS and WISE photometry in combination. Old stellar populations exhibit a global maximum in their SED at a wavelength of 1.6 μm, commonly referred to as the '1.6 μm bump'. Since LRGs possess very few young stars, this feature generally dominates their overall spectral energy distribution. The lowest wavelength channel in WISE is centered at 3.4 μm, causing LRGs that are at z~1 to be extremely bright in this band compared to the optical. As a result, the r-W1 vs. r-i color-color diagram (where W1 is the 3.4 μm WISE AB magnitude) provides an efficient tool for selecting high-redshift LRGs while avoiding stars. In this poster, we present new results from efforts to optimize the color cut used to select LRGs, yielding samples with a very low stellar contamination rate, but a high fraction of galaxies that are both at z>0.6 and intrinsically red in color. Studying their properties and distribution can also help us determine the mechanisms by which these rare objects form. We have tested this method using photometric redshifts and spectroscopic redshifts in the COSMOS field and DEEP2 fields respectively. LRGs selected with this method are the targets for future-generation surveys such as eBOSS and DESI and undergoing surveys like, SEQUELS BOSS ancillary

survey which aim at high precision measurement of BAO.

209 – HAD VI: History of Astronomy
Oral Session – National Harbor 3 – 07 Jan 2014 10:00 am to 11:30 am

209.01 – The Recurrent Nova T CrB; Two Discoveries from the 102,000 Magnitude Light Curves from 1855 to 2013 in Johnson B & V

Bradley E. Schaefer[1]

1. Louisiana State Univ., Baton Rouge, LA, United States.

Recurrent Nova T CrB erupted in 1866 and was the first well-observed nova eruption. The modern concept of nova developed only in the early 1900s, but many observers kept track of this mysterious variable. With a curious anticipatory warning from Leslie Peltier in 1945, T CrB erupted again in 1946. Recurrent novae are popularly featured as the solution to the supernova progenitor problem, so I collected an exhaustive historical light curve of T CrB from 1855-2013. I have collected magnitudes from dusty logbooks at the RAS, AAVSO, and Cambridge, and measured its brightness from archival plates in Sonneberg, Harvard, and Bamberg. More magnitudes have been pulled from the very-obscure early literature as well as from visual archives worldwide (primarily AAVSO). It is critical that these magnitudes (in visual, V, photographic, and B systems) all be correctly reduced to the modern Johnson B & V systems, and this was done by tracking down the original comparison stars and deriving the correct color terms for application to both T CrB and its comparison stars. These techniques are new, and I have never seen anyone apply such corrections to historical data. The result is a well-sampled light curve with 3100 V magnitudes from 1855-1946, 98400 V-magnitudes from 1946-2013, and 2500 B magnitudes from 1890-2013. Two new discoveries have come from all this historical data: (1) T CrB had a large and sharp increase in its orbital period across its 1946 eruption by 0.046%, implying a mass ejection of close to 0.00060 solar masses. Thus, the white dwarf ejected much more mass in 1946 than it accreted from 1866-1946, and T CrB is not a supernova progenitor. (2) Across both eruptions, T CrB was in a high state (1.0 mag bright in B) from T-8 to T-1 years and T+0 to T+8 years with sharp transitions. The well-known and still-mysterious second eruption at T+0.4 years is superposed on this high state. The drop from high to low state just before the eruption appears to be causally connected to the eruption. This phenomenon is completely unprecedented and unique, now providing a challenge to theorists.

209.02 – Barnard's Star: Planets or Pretense

Jennifer L. Bartlett[1], Philip A. Ianna[2]

1. US Naval Observatory, Washington, DC, United States. 2. University of Virginia, Charlottesville, VA, United States.

Barnard's Star remains popular with planet hunters because it is not only an extremely near, high proper motion star, but also the object of early planet-detection claims. In 1963, van de Kamp explained perturbations in its proper motion by the presence of a planet. In 1969, he produced another single-planet solution and a two-planet solution to the astrometric wobbles detected. At least 19 studies have failed to confirm his results using a range of techniques, including radial velocity, direct imaging, and speckle interferometry. However, most of them lacked the sensitivity to detect the planets he described, including astrometric studies at the McCormick and Naval Observatories. However, radial-velocity monitoring of Barnard's Star at Lick and Keck Observatories from 1987 through 2012 appears to have ruled out such planets. Based upon observations made at the Sproul Observatory between 1916 and 1962, van de Kamp claimed that Barnard's Star had a planet with about 1.6 times the mass of Jupiter and an orbital period of 24 years. After accounting for instrumentation effects that might have been partially responsible for his initial results, he continued to assert that this red dwarf had two planets. In his 1982 analysis of ~20,000 exposures collected between 1938 and 1981, he calculated that two planets with 0.7- and 0.5-Jupiter masses in 12- and 20-year orbits, respectively, orbited the second-closest stellar system to our own. Starting in 1995, the dramatic successes of radial velocity searches for extrasolar planets drove van de Kamp's unsubstantiated claims from popular consciousness. Although many low-mass stellar companions were discovered through astrometry, the technique has been less successful for planets: "The Extrasolar Planets Encyclopaedia" identifies one such discovery out of the 997 planets listed on 2013 September 23. Although Barnard's Star has lost its pretensions to hosting the first extrasolar planets known, its intrinsic properties will keep it under observation. NSF grant AST 98-20711, Litton Marine Systems, Levinson Fund, University of Virginia, Hampden-Sydney College, and US Naval Observatory supported this research.

209.03 – The Instability of Astrophysics Witnessed in the Twentieth Century

Martin Harwit[1]

1. Cornell University, Ithaca, NY, United States.

Scientific progress entails instabilities that advance a field; but excessive instability, often arising from misunderstandings, thwarts planning and adds cost. The history of 20th century astronomy provides insight on several factors that make astronomy and astrophysics exceptionally unstable. A fundamental source of instability is astronomy's inability, sometimes for decades at a time, to pursue discoveries of rare events systematically. Such delays inject levels of uncertainty in an observational science that are more readily avoided in the experimental sciences. Beneficial instabilities can arise through the import of novel theories and tools from sister sciences, industry or the military. Such imports, however, can also destabilize the field. Astronomy comprises many distinct disciplines, which need to interact coherently for a broader

understanding of the Cosmos to emerge. As the complexity of these disciplines' undertakings increases, and their respective uses of tools and vocabularies diverge, misunderstandings arise to threaten coherence. Misinformation can then cascade back and forth, with consequences similar to those of failures in electrical power grinds and financial meltdowns. A balance needs to be sought, which protects astrophysics against such failures, while permitting ready discourse so the whole field can benefit from genuine advances in its respective disciplines. I will discuss means by which the benefits of instabilities advancing the field may be retained while avoiding more damaging instabilities.

209.04 – The Largest Feasible Steerable Telescope

Kenneth I. Kellermann[1], Ellen N. Bouton[1]
1. NRAO, Charlottesville, VA, United States.

Ever since Grote Reber built a 32-ft steerable dish in 1937, successive generations of radio astronomers world-wide have designed larger and larger fully steerable filled aperture radio telescopes to address a variety of astronomical questions. Paced by the giant 250-ft radio telescope that was built at Jodrell Bank, starting in the 1950's NRAO, Caltech, and Smithsonian radio astronomers have discused the construction of a series of large steerable dishes ranging in size up to 600-ft in diameter. Although the need for a large steerable radio telescope was repeatedly recognized by the series of NRC decade reviews of astronomy, they were never given the highest priority and were never funded. Meanwhile, in the 1960s and 1970s the Parkes 64-m and the German 100-m telescopes became operational. A freak 1989 accident that caused the collapse of the 300-ft Green Bank transit telescope, led directly to the construction of the 100-m Green Bank Telescope with its novel unblocked aperture and adaptive surface, although by 1989, the 300-ft telescope had long outlived its designed lifetime, and had already been recommended for closure.

209.05 – Radio Frequency Interference and the National Radio Astronomy Observatory

Sierra Smith[1]
1. National Radio Astronomy Observatory, Charlottesville, VA, United States.

Radio frequency interference (RFI) and radio astronomy have been closely linked since the emergence of radio astronomy as a scientific discipline in the 1930s. Even before the official establishment of the National Radio Astronomy Observatory, protection against contemporary and future radio noise levels was seen as crucial to ensure success of any new observatory. My talk will examine the various local, regional, national, and international efforts enacted to protect NRAO and other American radio astronomy sites from RFI.

209.06 – Hubble Space Telescope: The Real 'First Light' Observation

G. F. Benedict[1], Barbara McArthur[1]
1. University of Texas, Austin, TX, United States.

To prove that a telescope will meet the design specifications laid down years previously, that it will eventually produce the science envisioned by those designers, they make a 'first light' observation, assess it, and pronounce "Here is our new telescope! It works!" That observation is often made with an instrument on the telescope that goes on to make many scientifically productive discoveries. The official Hubble Space Telescope (HST) first light image was secured by the Wide Field Planetary Camera on 5/20/1990, certainly a productive science instrument. The HST Fine Guidance Sensors (FGS), white-light interferometers, have an essential role to play in any scientific observation made with HST. They stabilize HST by locking onto guide stars. The Fine Guidance Sensors (FGS) have on their own produced useful and exciting astrometric scientific results ranging from parallaxes of Galactic Cepheids useful for the cosmic distance scale (Benedict et al. 2007, AJ, 133, 1810) to a demonstration of the degree of coplanarity in an exoplanetary system (McArthur et al. 2010, ApJ, 715, 1203). Hence, we argue that an FGS made the actual first light observation shortly after midnight on 1 May 1990 by successfully locking onto the V=12.97 star GSC 02666-01602. That FGS observation demonstrated light passing through the HST entire optical system and HST tracking. With a little (well, actually quite a lot of) tweaking, scientific results would surely flood forth. However, on May Day 1990 locking success was oddly sporadic. We had a few weeks more to enjoy our blissful ignorance of flapping solar panels and a mis-figured primary mirror, both of which contributed that night to our true first light observation problems. The events of that night and subsequent successful FGS astrometry are thanks to contributions over the years from L. Abramowicz-Reed, A. Bradley*, R. Duncombe, O. Franz, L. Fredrick, P. Hemenway, W. Jefferys, E. Nelan*, P. Shelus, D. Story*, W. van Altena, L. Wasserman*, and A. Whipple, some of whom (*) were lucky enough to be there with McArthur and Benedict early on May Day 1990.

209.07 – The National Science Foundation and the History of Science

Marc Rothenberg[1]
1. National Science Foundation, Arlington, VA, United States.

The National Science Foundation (NSF) is the major funder of the history of science in the United States. Between 1958 and

2010, the NSF program for the history of science has given 89 awards in the history of astronomy. This paper analyzes the award recipients and subject areas of the awards and notes significant shifts in the concentration of award recipients and the chronological focus of the research being funded.

210 – Jets and Outflows from AGN
Oral Session – National Harbor 11 – 07 Jan 2014 10:00 am to 11:30 am

210.01 – On the relationship between jet and broad emission lines variability in Flat Spectrum Radio Quasars

Giovanni Fossati[1]
1. Rice Univ., Houston, TX, United States.

Studies of the relationship between variations in the jet continuum emission and those of broad emission lines (and disk emission) can provide new clues about the structure of the central regions of jetted AGNs and properties of the outflow, such as the location of the active region. Thanks to Fermi and the large multiwavelength coverage that it stimulated (and supported) high quality data are now available for several blazars and this type of investigation is becoming possible and beginning to bear fruit. Recent results on 3C 454.3 (e.g. by Isler et al. 2013, Leon-Tavares et al. 2012) and other luminous FSRQ (e.g. PKS 1510-089, Isler et al.) reveal a connection between broad emission lines intensity and variations of the jet's non-thermal continuum. This suggests that the latter may be responsible for the line variability, a rather unexpected possibility, poorly explored, though not totally surprising. These new results and data certainly motivate a closer look at the possible (radiative) interplay between jet, accretion and "ambient gas", which is essential to understand observations and draw from them constraints on the geometry and dynamics of the AGN components, such as the location where the jet becomes dissipative. In particular the interpretation of the correlated (or not) variability requires to look more in depth at the relationship between the various "radiative signals", some of which may be responsible for causing variations in other components, examples being BLR radiation seeding inverse Compton emission in the jet, disk emission increasing BLR power, or jet emission ionizing part of the BLR as recently discussed. Because the jet "blob" itself moves nearly at the same speed of the "signals", the actual relationships among observables are somewhat at odds with the naive intuition. I will present results of our study of the observational implications/appearance of variations originating in different components and discuss the implications for the interpretation of recent novel observational work. GF acknowledges support from NNX11AO15G (Fermi GI), NNX12AE43G (NASA/ADAP)

210.02 – A Fast Moving Polarization Event in the Jet of BL Lacertae

Daniel C. Homan[1], Marshall H. Cohen[2], Yuri Y. Kovalev[3, 4], Matthew L. Lister[5], David L. Meier[6], Alexander B. Pushkarev[7, 8]
1. Denison Univ., Granville, OH, United States. 2. California Institute of Technology, Pasadena, CA, United States. 3. Astro Space Center of Lebedev Physical Institute, Moscow, Russian Federation. 4. Max-Planck-Institut für Radioastronomie, Bonn, Germany. 5. Purdue University, West Lafayette, IN, United States. 6. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States. 7. Pulkovo Observatory, St. Petersburg, Russian Federation. 8. Crimean Astrophysical Observatory, Crimea, Ukraine.

We report multi-epoch VLBA observations by the MOJAVE program of an unusual, fast-moving polarization feature in the parsec-scale radio jet of BL Lacertae. In most epochs, the inner jet is highly polarized, with electric field vectors along the local jet direction, indicating a dominant, projected magnetic field order transverse to the jet. In early 2008, an orthogonally polarized feature, indicating projected field order along the jet, developed and moved rapidly down the jet at superluminal speed. The apparent speed of this polarized feature is much faster than the Stokes-I components tracked by the MOJAVE program through this region (Lister et al. AJ in Press, http://arxiv.org/abs/1308.2713). As the polarized feature moves down the jet, it appears to be located on one side of the jet, with the traditional, longitudinal polarization on the far side. We discuss possible interpretations of this fast moving polarization event in the context of helical magnetic field models. The MOJAVE program is supported under NASA-Fermi grant 11-Fermi11-0019. YYK is partly supported by the Russian Foundation for Basic Research (project 13-02-12103) and the Dynasty Foundation.

210.03D – Probing the Disk-Jet Connection in Fermi Gamma-Ray Bright Blazars

Jedidah Isler[1], C. M. Urry[1], Paolo S. Coppi[1], Charles D. Bailyn[1], Ritaban Chatterjee[2], Giovanni Fossati[3], Erin W. Bonning[4], Laura Maraschi[5], Michelle Buxton[1]
1. Yale University, New Haven, CT, United States. 2. Presidency University, Kolkata, WB, India. 3. Rice University, Houston, TX, United States. 4. Quest University, Squamish, BC, Canada. 5. INAF - Osservatorio Astronomica di Brera, Brera, Milano, Italy.
Contributing teams: SMARTS

Relativistic jets in blazars produce radio through gamma-ray emission, via synchrotron radiation at long wavelengths and inverse Compton scattering at gamma-ray energies. Variability across these wavelengths allows us to estimate the densities and energies of the radiating particles. Yet, the physics of blazar jets is still uncertain; e.g., it is not clear whether the

gamma-rays come from sub- or kilo-parsec scales. The unprecedented temporal and spectral sensitivity of the Fermi Space Telescope has ushered in a new era of discovery and over the past 5 years I have obtained queue-scheduled, nightly optical-infrared (OIR) photometry and bi-weekly optical spectroscopy using the Small and Medium Aperture Research Telescope System (SMARTS) 1.3m+Andicam and 1.5m+RCSpec, in Cerro Tololo, Chile; totaling ~70 gamma-ray bright blazars that are detected nightly with Fermi. In my dissertation, I analyze 5 years of bi-monthly spectroscopy of 6 blazars. I find that the broad lines – which are presumably photoionized by the accretion disk – vary substantially less than the OIR continuum, which is dominated by the Doppler-beamed jet. However, during the largest gamma-ray flares in 3C 454.3 and PKS 1510-089, I see significant broad emission line variations, with lags on the order days and infer that the jet, in its brightest state, contributes significantly to photoionizing the broad-line clouds, meaning the gamma-emitting region is within the broad line region at sub-parsec scales. These variations are not seen at lower gamma-ray fluxes or in any other blazars we observed. I also describe inferences about the jet physics obtained from the SMARTS OIR photometry, which is well correlated with the gamma-ray flux for 11 blazars, with lags of less than one day, strongly supporting the inverse Compton model for gamma-ray production. In addition, color changes in the OIR constrain the ratio of thermal disk to non-thermal jet emission. The color evolution differs by source and also in a given source over timescales of years. In summary, the results of this dissertation provide strong constraints on the location of the gamma-emitting region and the spectral evolution of flaring blazars on short and long timescales.

210.04D – Interaction of Relativistic Jets with Their Environments

Susanna Kohler[1], Mitchell C. Begelman[1]
1. JILA, University of Colorado and NIST, Boulder, CO, United States.

Relativistic jets such as those emitted by active galactic nuclei are observed to be collimated over great distances, but the cause of this collimation is uncertain. Also not fully understood are the means by which these jets become accelerated to their extreme velocities. To probe these questions, I examine the possibility of collimation and acceleration of relativistic jets by the pressure of the ambient medium surrounding the jet base, in the limit in which the jet interior has lost causal contact with its surroundings. I model the jet with an ultrarelativistic equation of state, injected into an ambient medium that has a pressure that decreases as a power of spherical radius, $p \sim r^{n}$. Within the range $2<n<4$, the jet interior will be out of causal contact, but the outer layers of the jet gradually collimate toward the jet axis, leading to the formation of a shocked boundary layer. By constructing partially self-similar solutions to the fluid equations within this boundary layer, I examine the impact of the external pressure profile on the behavior of the fluid in the layer. I determine both the structure of the jet and the rate of energy conversion from internal to kinetic as the jet propagates outward, establishing both the collimation and acceleration profiles of the jet. I will discuss the differences in predicted jet behavior based on whether the jet is purely hydrodynamic or whether the model also includes the effects of a toroidal magnetic field threading the jet interior. I will also describe the conditions that create specific observed jet morphology, such as the "hollow cone" structure seen in jets such as M87. Finally, I will discuss the specific application of these models to describe the relativistic jets that are created by some tidal disruption events --- events in which a star passing near a supermassive black hole (SMBH) is torn apart by tidal forces, and the star material then accretes back onto the SMBH --- such as in the observations of Swift J1644+57.

210.05 – "New Proper Motion Measurements of the Superluminal Velocities in the M87 Optical Jet with HST"

Eileen T. Meyer[1], William B. Sparks[1], John A. Biretta[1], S. Tony Sohn[1], Jay Anderson[1], Roeland P. Van Der Marel[1], Colin A. Norman[2, 1], Masanori Nakamura[3]
1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Johns Hopkins University, Baltimore, MD, United States. 3. Academia Sinica Institute of Astronomy & Astrophysics, Taipei, Taiwan.

Using over 13 years of archival HST observations of the relativistic jet in the archetypal radio galaxy M87, we have produced astrometric speed measurements of the optically bright synchrotron emitting plasma components in the jet with unprecedented accuracy. Building on previous work showing the superluminal nature of the jet in the optical, we have found that the jet motion is incredibly complex, with both transverse motions and flux variations which can be seen very clearly by eye in the timeseries of deep exposures. These observations of M87 provide us with a unique dataset with which to refine theoretical models of the largescale jet structure, potentially addressing open questions such as the jet collimation mechanism, bulk acceleration and deceleration in the jet, and the presence of a helical structure. I will also present very recent results using data from the HST archive on the optical counterjet and nuclear regions of M87 and discuss the larger implications of these detailed studies of one of the most nearby AGN jets.

210.06D – Observation of Radio-Jet Driven Feedback

Hsin-Yi Shih[1], Alan N. Stockton[1]
1. University of Hawaii, Honolulu, HI, United States.

We seek to constrain the 3-D properties of radio-jet driven outflows through a study of extended emission-line regions

(EELRs) around quasars and radio galaxies, which according to the AGN unified model are the same type of objects viewed along different line-of-sights. EELRs are massive clumps of ionized gas found around about one-third of the AGNs with powerful radio jets. They can extend out to tens of kpc, and contain up to ~10^{10} Solar Masses. Previous studies of some luminous EELRs have shown that they are likely outflows driven by the radio jets. We took integral-field unit (IFU) observations of 40 quasars and radio galaxies with matched radio properties and redshifts to obtain information on the morphologies/kinematics of any associating EELRs. These data can help constrain the 3-D gas distribution and velocity structure of EELRs, reveal whether the EELRs are directly interacting with the radio jets, and whether the majority of these EELRs do indeed consist of outflow gas. We also present an IFU study focused on EELRs around 8 very young radio galaxies for comparison with the above sample. We show the evolutionary trends of the EELRs including changes in the alignments with the corresponding radio structures, the ionization mechanisms, and the kinematics.

211 – Lenses & Waves I
Oral Session – Maryland 1 – 07 Jan 2014 10:00 am to 11:30 am

211.01 – Concept and Analysis of a Satellite for Space-Based Radio Detection of Ultra-High Energy Cosmic Rays

Andrew Romero-Wolf[1], Peter Gorham[2], Jeff Booth[1], Pisin Chen[4], Riley M. Duren[1], Kurt Liewer[1], Jiwoo Nam[4], David Saltzberg[3], Harm Schoorlemmer[2], Stephanie Wissel[3], Pezhman Zairfian[1]
1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States. 2. University of Hawaii at Manoa, Honolulu, HI, United States. 3. University of California, Los Angeles, Los Angeles, CA, United States. 4. National Taiwan University, Taipei City, Taiwan.

We present a concept for on-orbit radio detection of ultra-high energy cosmic rays (UHECRs) that has the potential to provide collection rates of ~100 events per year for energies above 10^{20} eV. The synoptic wideband orbiting radio detector (SWORD) mission's high event statistics at these energies combined with the pointing capabilities of a space-borne antenna array could enable charged particle astronomy. The detector concept is based on ANITA's successful detection UHECRs where the geosynchrotron radio signal produced by the extended air shower is reflected off the Earth's surface and detected in flight.

211.02 – Coincidently Searching for Gravitational Waves and Low Frequency Radio Transients

Michael Kavic[1], Cregg Yancey[2], Peter S. Shawhan[2], Sean Cutchin[3,4], John H. Simonetti[5], Brandon Bear[5], Jr-Wei Tsai[5]
1. Long Island University, Brooklyn, NY, United States. 2. University of Maryland, College Park, MD, United States. 3. National Research Council, Washington, DC, United States. 4. Naval Research Laboratory, Washington, DC, United States. 5. Virginia Tech, Blacksburg, VA, United States.

The transient sky has become an important area of astrophysical study, especially with the appearance of recent fast transients, but little is known about the sources of these transients. One possible approach which can shed light on this area is multi-messenger astronomy using gravitational waves and prompt emission meter-wavelength radio to observe fast transients. This is made possible with gravitational-wave detectors such as LIGO, VIRGO, and GEO (IndIGO and KAGRA proposed or under construction) and phased-array radio-telescopes such LWA, LOFAR, LoFASM, and MWA. This talk presents a method for coincidence of gravitational wave and meter-wavelength radio observations to enable multi-messenger astronomy and discusses the optimization of gravitational-wave and radio sensitivities to attain effective combined observational sensitivities. It is shown that coincidence provides a 52.9% increase to the sensitivity distance for LIGO and a 200% increase to the SNR of radio arrays for particular cases.

211.03 – Ultra-relativistic X-ray counterparts of Compact Object Mergers.

Samaya Nissanke[1,2], Chris Hirata[2,1]
1. Caltech, Pasadena, CA, United States. 2. Ohio State University, Columbus, OH, United States.

Multiwavelength electromagnetic (EM) time-domain wide-field surveys and ground-based gravitational wave (GW) detectors will soon have the capabilities to detect and localize the mergers of binary compact objects (neutron stars and black holes). In this context, neutron star binary mergers, which contain ultra dense matter, provide a unique laboratory to study some of the most extreme astrophysical processes in the Universe. In this project, we study EM observations of these compact object mergers which are sensitive to the composition and the thermodynamic state of the matter. Remarkably, these observations will complement GW measurements, which will constrain the NS masses, spins, and orientation, and the dynamics of extreme curvature spacetimes. We present a new study of ultra-relativistic counterparts of compact object mergers produced by shock-breakout; in particular we demonstrate that our approach can lead to new promising insights onto strong field gravity.

211.04 – The first two years of gravitational-wave astronomy with Advanced LIGO and Virgo

Leo Singer[1], Larry Price[1], Alex Urban[2], Chris Pankow[2]
1. LIGO Laboratory, California Institute of Technology, Pasadena, CA, United States. 2. Leonard E. Parker Center for Gravitation, Cosmology, and Astrophysics, University of Wisconsin-Milwaukee, Milwaukee, WI, United States.

We anticipate the first direct detections of gravitational waves later this decade with Advanced LIGO and Virgo. Though these first discoveries will be seminal on their own, they may also have electromagnetic counterparts. During the first two years of

operation, 2015 through 2016, we expect the global gravitational-wave detector array to undergo several important changes: increased sensitivity and livetime, plus expansion from two detectors to the three. We model the detection rate and the sky localization accuracy across this transition. We have simulated a large number, astrophysically motivated population of binary neutron star mergers, and analyzed them using detection and sky localization codes that have been expressly built for real-time operation in the Advanced LIGO/Virgo era. From hundreds of simulated events, a picture of typical early Advanced LIGO detection candidates comes into focus, most occurring at particular Earth-fixed locations and most probability sky maps broadly fitting a single morphology. We conclude by discussing some implications for optical facilities that are considering searching these sky areas of hundreds of square degrees for optical transients.

211.05 – Astronomical guidance for directed searches for continuous gravitational waves

Benjamin Owen[1]
1. Penn State, University Park, PA, United States.

The LIGO Scientic Collaboration and Virgo Collaboration have published a search for continuous gravitational-waves from the non-pulsing neutron star in supernova remnant Cas A and, more recently, from the galactic center. More such searches, where the direction is known but no pulsar timing is available, are under way. I describe the astronomical criteria for good targets for such gravitational-wave searches, list classes of astronomical objects, and give examples of each class.

211.06 – Detecting Compact Objects with Microlensing

Jeremy Schnittman[1,2], Tyson Littenberg[3], Kailash C. Sahu[4], Nicholas Thieme[5]
1. NASA/GSFC, Greenbelt, MD, United States. 2. Joint Space Science Institute, College Park, MD, United States. 3. Northwestern University, Evanston, IL, United States. 4. STScI, Baltimore, MD, United States. 5. Rensselaer Polytechnic Institute, Troy, NY, United States.

We calculate the light curves of galactic bulge stars magnified via microlensing by stellar-mass binary black holes and neutron stars along the line-of-sight. We show the sensitivity to measuring various lens parameters for a range of survey cadences and photometric precision. Astrometric observations with HST and WFIRST will provide powerful additional constraints on the lens parameters and help break fundamental degeneracies of the problem. We discuss the implications of these observations for theories of binary formation and evolution.

211.07 – Detection and measurement of heavy black holes

Philip Graff[1], Alessandra Buonanno[2], Bangalore S. Sathyaprakash[3]
1. NASA/GSFC, Greenbelt, MD, United States. 2. University of Maryland, College Park, MD, United States. 3. University of Cardiff, Cardiff, United Kingdom.

In this study, we perform a Bayesian analysis of massive binary black hole systems using effective-one-body waveforms. Our waveform model includes merger and quasi-normal modes that are tuned to numerical relativity results for many spherical modes of radiation. The additional modes help determine the parameters of progenitor binaries even when their inspiral phase might not be in the sensitivity band of a detector. We show the importance of including sub-dominant spherical modes beyond the dominant (2,2) mode. We investigate the dependence of detection, measurement uncertainty, and measurement biases from both not including higher order modes and as a function of source parameters. Spin effects will be considered for the first time in this framework with use of the aligned-spin effective-one-body waveform for parameter estimation. We also consider the astrophysical rates for heavy black hole binaries and the chances of detecting them with the advanced detector network.

211.08 – Uncovering the population of binary black holes in the local universe with space-based gravitational wave detectors.

Jesus Hinojosa[1], Matthew Benacquista[1], Alberto Mata[1]
1. Center for Gravitational Wave Astronomy, Brownsville, TX, United States.

Stellar mass black hole binaries may have individual masses between 10-80 solar masses. Some of these systems may emit gravitational waves at frequencies detectable at Megaparsec distances by space-based gravitational wave observatories. Using the selection effects of observing these systems with detectors similar to the Laser Interferometer Space Antenna found from a generated population of binary black holes that covers a reasonable parameter space and calculating their signal-to-noise ratio. We populate the galaxies in our nearby (less than 30 Mpc) universe with binary black hole systems drawn from a distribution found in the Synthetic Universe to determine the likely event rate of detectable binaries from galaxies in the nearby universe.

212 – Pulsars & Neutron Stars III

Oral Session – National Harbor 13 – 07 Jan 2014 10:00 am to 11:30 am

212.01 – Studies of Pulsars Using Space VLBI with RadioAstron

Michael Johnson[2], Carl Gwinn[1], Mikhail Popov[3], Tatyana Smirnova[4], Vladimir Shishov[4], James Anderson[5], Andrei Andrianov[3], Norbert Bartel[6], Sarah Buchner[7], Adam Deller[8], Warren Hankey[9], Shinji Horiuchi[10], Bhal Chandra Joshi[11], Nikolay Kardashev[3], Ramesh Karuppusamy[5], Yuri Y. Kovalev[3], Michael Kramer[5], Jamie McCallum[9], Chris Phillips[12], Jonathan Quick[7], John Reynolds[12], Alexey Rudnitsky[3], Yegor Safutdinov[3], Vladimir Soglasnov[3], A. Tzioumis[12], Anton Zensus[5], Vladimir Zhuravlev[3]

1. Univ. California, Santa Barbara, Goleta, CA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. Lebedeev Physical Institute, Moscow, Russian Federation. 4. Pushchino Radio Astronomy Observatory, Pushchino, Russian Federation. 5. Max-Planck-Institut fur Radioastronomie, Bonn, Germany. 6. York University, Toronto, ON, Canada. 7. Hartebeesthoek Radio Astronomy Observatory, Krugersdorp, South Africa. 8. ASTRON, Dwingeloo, Netherlands. 9. University of Tasmania, Hobart, TAS, Australia. 10. Canberra Deep Space Communication Complex, NASA, ACT, Australia. 11. National Centre for Radio Astrophysics, Pune, India. 12. Australia Telescope National Facility, Epping, NSW, Australia.
Contributing teams: the RadioAstron Pulsar Group

The advent of space VLBI with RadioAstron has increased accessible baselines by an order of magnitude, up to the distance of the moon. The exquisite resolution afforded by these baselines provides a unique opportunity to probe nearby pulsars and the interstellar plasma that scatters their radio emission. We summarize the Early Science Program for pulsar study with RadioAstron and discuss general properties of visibilities on space-ground baselines for several objects. We present preliminary results on B0950+08, which lies within the Local Bubble and is weakly scattered. These results indicate markedly different scattering characteristics than those of more distant pulsars. We also present observations of the Vela pulsar on Earth-space baselines, so long that they should completely resolve the scattering disk.

212.02D – Investigating astrophysical plasmas using LOFAR observations of pulsars

Charlotte Sobey[1, 2]
1. ASTRON, Dwingeloo, Netherlands. 2. MPIfR, BONN, Germany.
Contributing teams: LOFAR collaboration

Observations of pulsars using next generation low-frequency radio telescopes, for example LOFAR (the Low Frequency Array, a low-frequency Square Kilometre Array pathfinder), provide powerful probes of astrophysical plasmas. In particular, unprecedented precision on Rotation Measures (RMs) and Dispersion Measures (DMs) towards pulsars improves measurements of the magnetic field of foreground sources, including that of the ISM, and potentially globular clusters, the heliosphere, and temporal variations therein. The large fractional bandwidth and collecting area of LOFAR combine to produce the highest-quality polarisation profiles of pulsars below 200 MHz to date. These data are well suited for using the novel technique of Rotation Measure (RM) synthesis to achieve unprecedented precision on Faraday rotation measurements. The time- and position-dependent ionospheric Faraday rotation is modelled (and subtracted) using total electron content maps and the International Geomagnetic Reference Field. The results of this model have been verified using long-track LOFAR pulsar observations. Combining the accurate RMs and DMs from LOFAR pulsar observations provides an efficient method to determine the average magnetic field parallel to the line of sight. I will present an initial catalog of these highly accurate RMs, towards measuring the structure of the magnetic field in the Galaxy. I will also highlight interesting results from a mode-changing pulsar, yielding insights into the pulsar magnetosphere.

212.03 – Radio Pulsars - Intermittent Particle Accelerators

Andrey Timokhin[1]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States.

Although radio pulsars had been discovered almost five decades ago, their emission mechanisms are still not identified, and even the global structure of pulsar magnetosphere, where almost all pulsarradiation is produced, remains unknown. One important aspect of almost all pulsar models is particle acceleration and creation of electron-positron plasma which fills pulsar magnetosphere. It is widely believed that pulsar emission mechanisms are tightly coupled to the generation of pair plasma. In the recent time significant progress has been achieved in both theoretical as well as observational studies of

pulsars, which can be partially attributed to the advent of powerful computers and the launch of Fermi gamma-ray observatory. Recent studies has shown that the generation of pair plasma strongly depends on the current density in the magnetosphere and is always going intermittently, when bursts of pair formation are followed by quiescent phase with no particle acceleration. Recent non-stationary models of pair creation seems to be very promising in solving the problem of high plasma density seen in pulsar wind nebulae and offer a possibility for a natural explanation of pulsar radio emission. I present a brief overview of these results.

212.04 – SGR J1745-29: Swift discovery and monitoring of a new SGR near Sgr A*

Jamie A. Kennea[1], David N. Burrows[1], Chryssa Kouveliotou[3], David Palmer[9], Ersin Gogus[5], Yuki Kaneko[5], Phil Evans[4], Nathalie Degenaar[6], Mark Reynolds[6], Jon M. Miller[6], Rudy Wijnands[7], Kaya Mori[8], Neil Gehrels[2]
1. Penn State Univ., State College, PA, United States. 2. NASA/GSFC, Greenbelt, MD, United States. 3. NASA/MSFC, Huntsville, AL, United States. 4. University of Leicester, Leicester, United Kingdom. 5. Sabanci University, Istanbul, Turkey. 6. University of Michigan, Ann Arbor, MI, United States. 7. University of Amsterdam, Amsterdam, Netherlands. 8. Columbia University, New York, NY, United States. 9. Los Alamos National Lab, Los Alamos, NM, United States.

Starting in 2013 February, Swift has been performing short daily monitoring observations of the G2 gas cloud near Sgr A* with the X-Ray Telescope to determine whether the cloud interaction leads to an increase in the flux from the Galactic center. On 2013 April 24 Swift detected an order of magnitude rise in the X-ray flux from the region near Sgr A*. Initially thought to be a flare from Sgr A*, detection of a short hard X-ray burst from the same region by the Burst Alert Telescope suggested that the flare was from an unresolved new Soft Gamma Repeater, SGR J1745-29. Here we present the discovery of SGR J1745-29 by Swift, including analysis of data before, during, and after the burst. We cover the entire light-curve of the SGR outburst so far, from discovery through to the source entering a Swift Sun constraint in November 2013. Thanks to the interest in G2 and it's location near the Galactic Center, SGR J1745-29 has become one of the best monitoring SGRs in outburst yet seen.

212.05D – The neutron star radius and the dense-matter equation of state

Sebastien Guillot[1], Mathieu Servillat[2], Natalie Webb[3], Robert E. Rutledge[1]
1. McGill University, Montreal, QC, Canada. 2. CEA Saclay, Gif-sur-Yvette, France. 3. IRAP/CNRS, Toulouse, France.

A physical understanding of the behaviour of cold ultra-dense matter - at and above nuclear density - can only be achieved by the study of neutron stars, and the thermal emission from quiescent low-mass X-ray binaries inside globular clusters have proven very useful for that purpose. The recent 1.97 ± 0.04 Msun measurement for the radio pulsar PSR 1614-2230 suggests that strange quark matter and hyperons/kaons condensate equations of states (EoS) are disfavoured, in favour of hadronic "normal matter" EoSs. Over much of the neutron star mass-radius parameter space, "normal matter" EoSs produce lines of quasi-constant radii (within the measurement uncertainties, of about 10%). We present a simultaneous spectral analysis of several globular cluster quiescent low-mass X-ray binaries where we require the radius to be the same among all neutron stars analyzed. The Markov-Chain Monte-Carlo method and the Bayesian approach developed in this analysis permits including uncertainties in the distance, in the hydrogen column density, and possible contributions to the spectra due to un-modelled spectrally hard components. Our results suggest a neutron star radius much smaller than previously reported, with a value Rns = 9.1 ± 1.4 km, at 90% confidence, using conservative assumptions, which suggests that neutron start matter is best described by the softest "normal matter" equations of state.

212.06 – The Neutron Star Interior Composition Explorer (NICER): Future X-ray Astrophysics from the International Space Station

Zaven Arzoumanian[1, 2], Keith Gendreau[2]
1. CRESST/USRA, Greenbelt, MD, United States. 2. NASA GSFC, Greenbelt, MD, United States.
Contributing teams: NICER team

In April 2013, NASA announced the selection of its newest planned high-energy astrophysics mission, the Neutron star Interior Composition Explorer (NICER), expected to launch in late 2016. As a successor to the now-decommissioned but highly productive Rossi X-ray Timing Explorer, NICER offers capabilities that will appeal to a large community of prospective users. We present an overview of the NICER mission, its core science agenda, and a brief discussion of NICER's anticipated contributions across an array of X-ray astrophysics investigations, enabled by a proposed Guest Observer program. NICER is designed to probe the exotic interiors of neutron stars, revealing the fundamental physics of dense matter that exists nowhere else in nature, a longstanding unsolved problem. NICER's key approach consists of inferring neutron star masses and radii through time-resolved soft X-ray spectroscopy of pulsars with millisecond spin periods. In addition to exploring neutron star structure, NICER will study dynamic phenomena powered by accretion and strong gravity, and the extreme

physics of pulsar magnetospheres, perhaps the most powerful cosmic particle accelerators known. NICER is particularly timely given the tremendous rate of millisecond-pulsar discovery enabled by NASA's Fermi gamma-ray telescope. NICER brings together high-heritage technologies -- such as grazing-incidence foil optics and silicon drift detectors -- in an innovative configuration, and exploits established infrastructure on the International Space Station to offer a low-risk, highly capable instrument to the X-ray astrophysics community. NICER's unique combination of photon time-tagging precision, energy resolution, and sensitivity in the soft X-ray (0.2-12 keV) band represents both a novel capability for studying neutron stars and exploration of new discovery space in time-domain astrophysics.

212.07 – A new crystalline phase in magnetar crusts

Simin Mahmoodifar[1], Paulo F. Bedaque[1], Srimoyee Sen[1]
1. Physics, University of Maryland, College Park, MD, United States.

We show that ions at the low densities and high magnetic fields relevant to the outer crust of magnetars form a novel crystalline phase made of strongly coupled filaments of ions along the magnetic field. This is due to a long-range oscillatory behavior in the ion-ion potential along the magnetic field that is caused by anisotropic electronic screening of ions in this direction (found by Sharma & Reddy 2011). We show that this long-range oscillatory term in the ion-ion potential (Friedel oscillations), that has been neglected in previous studies of neutron star structure at high magnetic fields, has a strong effect on the structure and elastic properties of the crystal lattice in the outer crust. In fact, we find that due to this long-range force the elastic constants (the bulk and shear moduli) that are dominated by the longitudinal structure of the lattice are significantly larger than that of a usual bcc Coulomb crystal at comparable densities. This has potentially interesting implications for the Quasi-periodic Oscillations (QPOs) seen in the X-ray flux of magnetars during their giant flares. These QPOs have been linked to global torsional vibrations within the star's crust, the frequencies of which are a function of the shear modulus of the crust.

213 – Spitzer Space Telescope: The Next Ten Years

Special Session – Potomac Ballroom C – 07 Jan 2014 10:00 am to 11:30 am

NASA's Spitzer Space Telescope passed its ten-year launch anniversary in 2013 marking a decade of exciting, ground-breaking infrared science programs. The observatory excels at observations aimed at characterizing exoplanets, brown dwarf weather, and studies of the high-redshift universe, and continues to support programs across a wide spectrum of astrophysical disciplines. The science synergy with other NASA missions, in particular the Hubble Space Telescope and the Kepler Observatory, continues to be outstanding. The current engineering assessment shows that Spitzer can continue operations into at least 2017. While it will not be taking observations in ten years, Spitzer observations will have a major impact on future missions and science programs planned in the next decade. Spitzer science programs already play a major role in defining the source lists and science for the James Webb Space Telescope. This special session highlights the current state of the art of Spitzer science programs in the fields of high-redshift galaxies, high-redshift clusters, exoplanets, and stellar variability. The speakers will also look to the future when Spitzer will have ceased to operate but will continue to have a substantial scientific impact.

213.01 – Introduction: Spitzer -- The Next Ten Years

Lisa J. Storrie-Lombardi[1]
1. Caltech, Pasadena, CA, United States.

NASA's Spitzer Space Telescope passed its ten-year launch anniversary in August 2013 marking a decade of exciting, ground-breaking infrared science programs. The observatory excels at observations aimed at characterizing exoplanets, brown dwarf weather, and studies of the high-redshift universe, and continues to support programs across a wide spectrum of astrophysical disciplines. The science synergy with other NASA missions continues to be outstanding. The current engineering assessment shows that Spitzer can continue operations into at least 2017. The talks in this special session highlight the current state of the art of Spitzer science programs in the fields of high-redshift galaxies, high-redshift clusters, exoplanets, and stellar variability. The speakers will also look to the future when Spitzer will have ceased to operate but will continue to have a substantial scientific impact.

214.05 – Spitzer's Past and Future Exoplanet Legacy

Sara Seager[1]
1. Massachusetts Institute of Technology, Cambridge, MA, United States.

Spitzer initiated and revolutionized the field exoplanet atmosphere studies from the first secondary eclipse measurements announced in 2005. Since that time Spitzer has accrued a long list of compelling exoplanet findings, including: thermal phase curves for atmospheric dynamics and heat transport constraints; inference of clouds; evidence for thermal inversions; and suggestions of high C/O atmospheric ratios. Cold Spitzer continued an exoplanet legacy by: discovery of transits of 55 Cnc e; unique atmosphere insights either alone or in tandem with visible wavelength telescopes; and validation of Kepler small planet candidates via primary eclipse measurements at Spitzer wavelengths to rule out astrophysical false positives. The future of Spitzer's exoplanet program remains bright via continued observations of warm and hot exoplanet transits, secondary eclipses, and thermal phase curves, including small planets via long-duration campaigns.

213.02 – Pushing the Frontiers to z>10 with the Spitzer Space Telescope

Peter L. Capak[1], Charles L. Steinhardt[1], Josh S. Speagle[2], Andreea Petric[1], Martin Elvis[2]
1. Caltech, Pasadena, CA, United States. 2. Harvard Smithsonian Center for Astrophysics, Cambridge, MA, United States.
Contributing teams: The Frontiers Fields Team, The SPLASH team, The COSMOS team

Spitzer has proven to be incredibly sensitive to high-redshift systems, recently measuring the masses of z~10 galaxies. The Spitzer Frontier fields have been undertaken to expand the number of galaxies with mass measurements at z~7-12 by using foreground clusters as gravitational lenses. At slightly lower redshifts, the Spitzer Large Area Survey with Hyper-Suprime-Cam (SPLASH) is designed to explore the nature of large scale structure at 3<z<7, link early galaxy formation during the same epoch to dark matter haloes via clustering, and explore the transient sky at infrared wavelengths in order to measure the initial mass function of stars and the properties of AGN accretion. I will begin by presenting some early data from the Spitzer Frontier fields that will be 50% complete by January 2014. I will then show some early results from SPLASH, including robust measurements of the star formation-mass relation and mass function at z~3-6 along with preliminary constraints on the initial mass function at z>4. I will then conclude with prospects for the next 10 years of Spitzer data including synergies with Euclid, JWST, WFIRST, and other next-generation facilities.

213.03 – Spitzer and Variable Young Stars: Shining a Spotlight on Circumstellar Disks

Ann Marie Cody[1]

1. Caltech, Pasadena, CA, United States.
Contributing teams: The CSI 2264 Team

Since its launch in 2003, the Spitzer Space Telescope has helped to uncover hundreds of disk bearing young stars in clusters by detecting their infrared excesses. Study of the spectral energy distributions of these objects has shed light on disk evolution, dispersal, and the relationship to planet formation. With the start of the Warm Spitzer Mission, mid-infrared time series observations have opened up a new window into the dynamic nature of these systems. Not only are young stellar objects (YSOs) highly variable, but so are their disks! I will review recent findings on mid-infrared variability in young stars, highlighting the Young Stellar Object Variability project and the joint Spitzer/CoRoT Coordinated Synoptic Investigation of NGC 2264. These efforts have resulted in a comprehensive census and categorization of YSO flux behavior at 0.5 through 4.5 microns, on timescales from hours to months. We now have evidence for multiple simultaneous variability mechanisms, supporting the picture of a highly dynamic star-disk system.

213.04 – The Spitzer View of Galaxy Clusters in the Distant Universe

Casey J. Papovich[1]
1. Texas AandM University, College Station, TX, United States.

One of surprising results of Spitzer Space Telescope was its ability to find galaxy clusters (and proto-clusters) in the distant universe, well beyond redshifts of one. Galaxies in clusters are massive and contain homogeneous stellar populations, and their rest-frame light peaks at 1-2 micron, they are very bright in the IRAC bandpasses out to redshifts of two and beyond. Deep, wide area surveys with Spitzer/IRAC provided an viable alternative method, with different selection biases to other cluster searches (e.g., X-rays). In this contribution, I will provide a summary of surveys and techniques using Spitzer that successfully identified galaxy clusters out to redshifts of nearly two. Clusters at these redshifts are still in the act of forming, but by studying the properties we begin to understand the co-evolution of clusters and their constituent galaxies. I will also discuss current (and potentially future) larger, ambitious programs with Spitzer to identify complete samples of cluster progenitors in the distant Universe, and I will summarize what we hope to learn from these surveys.

214 – Star Formation II
Oral Session – National Harbor 12 – 07 Jan 2014 10:00 am to 11:30 am

214.01 – Do Binary Stars Primarily Originate in Multiple Protostar Systems?

Alan P. Boss[1]

1. Carnegie Inst. of Washington, Washington, DC, United States.

Magnetic fields have a major effect on whether the dynamic collapse of dense molecular cloud cores results in formation of single protostars or fragmentation into binary or multiple protostar systems. We present three-dimensional models of the collapse of magnetic molecular cloud cores using the adaptive mesh refinement (AMR) code Enzo2.2 in the ideal magnetohydrodynamics approximation. The cloud cores are initially either prolate or oblate, centrally condensed clouds with masses of 1.73 or 2.73 solar masses, respectively, seeded with random density perturbations at the 10% level. The radial density profiles are Gaussian, with central densities 20 times higher than boundary densities. A barotropic equation of state is used to represent the transition from low density, isothermal phases, to high density, optically thick phases, with a critical density of 1e-14 g/cc and a polytropic exponent of 7/5 in the high density regime. The initial magnetic field strength is varied from 6.3 to 100 microgauss, corresponding to clouds that are strongly to marginally supercritical, respectively, in terms of the mass to magnetic flux ratio (initially subcritical clouds contract, but do not collapse). The magnetic field is initially uniform and aligned with the cloud's rotation axis, with initial uniform rotation rates of 1e-14 to 3.2e-13 rad/s being studied, leading to initial ratios of rotational to gravitational energy of 1e-4 to 1e-1. Two significantly different outcomes result: (1) collapse to form single protostars with significant spiral arms, and (2) collapse and fragmentation into multiple protostar systems, with multiple spiral arms. The transition between these two outcomes depends primarily on the initial magnetic field strength, with fragmentation occurring for mass to flux ratios greater than about 14 times the critical ratio. The initial rotation rate primarily influences the orbital separation of the fragments. Oblate clouds typically fragment into about 9 clumps, compared to about 4 for the prolate clouds. Multiple system formation is the rule in either case, suggesting that binary stars are primarily the result of the orbital dissolution of multiple protostar systems.

214.02 – Inferring the Evolutionary Stages of High-mass Star-forming Regions from Chemistry

Siyi Feng[1], Henrik Beuther[1], Thomas Henning[1], Dmitry Semenov[1], Hendrik Linz[1]

1. Max-Planck Institute for Astronomy, Heidelberg, Germany.

Contributing teams: Max-Planck Institute for Astronomy

The earliest phases of the high-mass star-forming regions (HMSFRs) have so many extremely complicated astrophysical processes, such as infall, outflows, and fragmentations that kinematic studies are not enough to understand all the mysteries, therefore, chemistry has developed into a powerful tool in probing the nature of them. Using PdBI at 1.3 mm, we observed two typical HMSFRs, NGC 7538 S and NGC 7538 IRS. Continuums are presented, the spectra from different substructures in each source are extracted and the intensity-integrated distribution maps for different species are imaged. We then calculate their column densities, and abundances in each identified substructure, assuming local thermal equilibrium, optically thin and uniform widths lines for all species. With spatial resolution of 0.4'' (800 AU), NGC 7538 S fragmentations into at least three cores, having similar continuum flux densities but different kinematic temperatures nor line properties, and exhibiting evolutionary sequence from northeast to southwest: MM1 is more evolved, and is a typical hot molecular core, associated with an accretion disk and several outflows, which enhance certain molecular abundances in the projected direction; MM2 is a high mass protostar object, where majority of molecules have abundances lower than in MM1, except for the lower temperature tracers, e.g., ketene, formaldehyde; whereas MM3 is still a cold starless core, and the spectral emissions in this substructure are only from molecules with low vibration temperatures. Since they are embedded in the same cluster but behave different properties, they should have the similar ages but different warm-up timescales. In comparison, IRS1 remains unresolved, though, large amount of complex organic molecules indicates it as the most evolved hot core in all the substructures here we studied. Absorption feature only appears on the spectrum extracted from the continuum peak, and that may come from its precession accretion disk, together with the outflow whose collimated cavity is along the line of sight; while at least three odd emission lines on this spectrum may be owing to the population inversion of methanol.

214.03 – Radio Emission from Stars in the Central Young Cluster Orbiting Sgr A*

Farhad Yusef-Zadeh[1], D. A. Roberts[1], Howard A. Bushouse[3], William D. Cotton[2], M. Wardle[4], Marc Royster[2]

1. Northwestern University, Evanston, IL, United States. 2. NRAO, Charlottesville, VA, United States. 3. STScI, Baltimore, MD, United States. 4. Mcquarie, Sydney, NSW, Australia.

Radio continuum observations of the Galactic center have been carried out in four different epochs between July and August 2011 at 7mm using the VLA in its A configuration. We combined these data and made a high dynamic range image of the inner 30" of Sgr A* with a resolution of ~82x42 milliarcseconds with an rms noise 61 microJy. After the comparison of 7mm images with H, K and L images taken with the VLT during the same epoch, we identify at least 50 radio sources. Most of

these sources coincide with infrared identified stellar sources associated with the central cluster. We used the accurate position of radio stars to register the radio and infrared frames at a smaller angular distance from Sgr A* (~5") than had been made in earlier studies based on SiO masers (Menten et al. 1997; Reid et al, 2003). Sensitive radio measurements should be able to potentially discover highly extincted stellar sources that are not detected at near-IR wavelengths. We discuss the origin of radio emission from stars in the central cluster. We also present dark features in Galactic Center radio images that are the imprints of envelopes of dusty stars and molecular clouds.

214.04 – A Census of Diverse Environments in Infrared Dark Clouds: Where Do Massive Stars Form?

William J. Dirienzo[1], Crystal L. Brogan[2], Remy Indebetouw[1, 2], Claire J. Chandler[3], Kathryn E. Devine[4]

1. University of Virginia, Charlottesville, VA, United States. 2. National Radio Astronomy Observatory, Charlottesville, VA, United States. 3. National Radio Astronomy Observatory, Socorro, NM, United States. 4. The College of Idaho, Caldwell, ID, United States.

Infrared Dark Clouds (IRDCs) harbor the earliest phases of massive star formation and complex astrochemistry. IRDCs are extraordinarily dense and cold objects of dust and molecular gas arranged in filamentary or globule structures with compact cores. Many of the compact molecular and millimeter cores are known to host massive protostars from a variety of star formation indicators. We have used the GBT and the VLA to map ammonia and CCS in nine IRDCs to reveal the temperature, density, and velocity structures and explore chemical evolution in the dense cores. Ammonia is an ideal molecular tracer for these environments as its critical density is appropriate for IRDCs, and nitrogen-bearing species are not prone to dust-grain freeze-out even in these cold regions. The hyperfine structure allows unambiguous determination of the optical depth and thus the column density, and using two rotational transitions allows determination of the temperature. By imaging ammonia and CCS in these regions, we can use their abundance ratios as "chemical clocks" to determine whether the starless cores are indeed less evolved. With this data we will begin to address the questions of how these two classes of cores are alike and different and whether the quiescent cores are likely to eventually form stars or not. We further investigate the structure and kinematics of the IRDCs, revealing gradients and colliding sub-clouds that elucidate the formation process of these structures and their protostars. A comprehensive study of IRDCs in molecular gas tracers with both total power and high resolution is necessary to truly understand the relationship between IRDCs and massive star formation.

214.05 – Kinematics and Temperature Structures of Filaments in Serpens Main and Serpens South

Katherine Lee[1], Lee G. Mundy[1], Manuel Fernandez Lopez[2], Shaye Storm[1], Leslie Looney[2], Dominique Segura-Cox[1], Peter J. Teuben[1], Erik Rosolowsky[3], Hector G. Arce[4], Yancy L. Shirley[5], Adele Plunkett[4], Andrea Isella[6], John J. Tobin[7]

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We present a study of filaments in Serpens Main and Serpens South cluster regions based on N2H+(1-0) observations from the CARMA Large Area Star-formation Survey (CLASSy) and dust continuum images from the Herschel Space Observatory. Serpens Main and Serpens South are active star formation regions with prominent filamentary structures; however, the role of the filaments in the cluster formation is unclear. This study of filament structure and kinematics with high-angular resolution data (7 arcsecs), particularly in revealing possible infall signatures, provides physical insight to this question. Using the Herschel data, we estimate the temperature in and along filaments for comparison with their gas kinematics, spatial distribution, and N2H+(1-0) emission, to better understand their role in current star formation activities.

214.06 – Dendrogram Analysis of Large-Area CARMA Images in Perseus: the Dense Gas in NGC 1333, Barnard 1, and L1451

Shaye Storm[1], Lee G. Mundy[1], Peter J. Teuben[1], Katherine Lee[1], Leslie Looney[2], Manuel Fernandez Lopez[2], Erik Rosolowsky[3], Hector G. Arce[4], Yancy L. Shirley[5], Dominique Segura-Cox[2], Andrea Isella[6]

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Contributing teams: CLASSy Team

We present spectral line maps of the dense gas across 400 square arcminutes of the Perseus Molecular Cloud, focused on NGC 1333, Barnard 1, and L1451. We constructed these maps as part of the CARMA Large Area Star-formation Survey (CLASSy), which is a CARMA key project that connects star forming cores to their natal cloud environment. This is achieved by leveraging CARMA's high angular resolution, imaging capability, and high efficiency at mosaicing large areas of the sky. CLASSy maps capture the structure and kinematics of N2H+, HCN, and HCO+ J=1-0 emission from thousand AU to parsec scales in three evolutionarily distinct regions of Perseus (in addition to two regions in Serpens). We show results from a non-binary dendrogram analysis of the Perseus N2H+ emission, which answers questions about the turbulent properties of the dense gas across evolutionary stages and across the range of size scales probed by CLASSy. There is a flat relation between mean internal turbulence and structure size for the dense gas in NGC 1333 and Barnard 1, but the magnitude of internal turbulence increases with nearby protostellar activity; the dense gas in the B1 main core and NGC 1333, which have active young stars, are characterized by mostly transonic to supersonic turbulence, while the filaments and clumps southwest of the B1 main core, which have no active young stars, have mostly subsonic turbulence. We have recently completed the observations of L1451, and results for that region will be revealed at the meeting. Released CLASSy data products can be found on our project website.

214.07 – PROTOBINARY EVOLUTION DRIVEN BY MAGNETIC BRAKING

Bo Zhao[1], Zhi-Yun Li[1], Kaitlin M. Kratter[2]
1. University of Virginia, Charlottesville, VA, United States. 2. JILA, University of Colorado, Boulder, CO, United States.

The majority of stars are in multiple systems, especially binaries. Such objects form in dense cores of molecular clouds that are observed to be strongly magnetized. Most previous studies of binary formation have either ignored magnetic fields or focused on the initial core fragmentation into binary seeds. Here I focus on the effects of the magnetic field on the orbital evolution of the protobinary during the main accretion phase, after a pair of stellar seeds have formed. By simulating a \'seed\' binary system with the sink particle treatment, we show that magnetic field plays a crucial role in removing the gas angular momentum and shrinking the binary separation. Through magnetic braking, strong magnetic field is very effective in suppressing the formation of circumstellar disks and circumbinary disk along with its spiral arm structures. The magnetic field can also be responsible for the population of the low mass-ratio binaries in the observed distribution. The magnetically-braked material will have equal chance of being accreted onto either binary seed, instead of the preferential accretion onto the secondary when magnetic field is absent. Furthermore, large field mis-alignment helps to produce rotationally-supported circumbinary disks even for relatively strong magnetic fields, by weakening the magnetically-dominated structure close to the binary. Hence to explain the observed properties of binaries, the magnetic effects deserve more careful considerations in the larger context of binary formation in future studies.

214.08D – From clouds to cores to envelopes to disks: a multi-scale view of magnetized star formation

Charles Hull[1], Richard L. Plambeck[1]
1. UC Berkeley, Berkeley, CA, United States.
Contributing teams: TADPOL survey team

Magnetic fields are thought to play an important role in the formation of stars. However, that importance has been called into question by previous observations showing misalignment between protostellar outflows and magnetic fields (B-fields), as well as inconsistency in field morphology between 10,000 and 1000 AU scales. To investigate these inconsistencies, we used the 1.3 mm full-Stokes polarimeter — which I tested, installed, and calibrated for CARMA, a mm-wave interferometer — to map dust polarization with ~2.5" resolution toward 29 star-forming cores and 8 star-forming regions as part of the TADPOL survey. We find that a subset of the sources have consistent B-field orientations between the large (~20") scales measured by single-dish submm bolometers and the small scales measured by CARMA. Those same sources also tend to have higher fractional polarizations (measured by CARMA), presumably because the B-fields are less twisted by dynamic effects. However, even in these sources, which seem to have retained the memory of the global B-field direction, the fields in the cores are misaligned with the disks and outflows in the central protostars — a key result of the TADPOL survey. Furthermore, the cores with lower polarization fractions tend to have B-fields that are perpendicular to outflows, which suggests that in these sources the B-fields have lost the memory of the larger-scale global field, and have been wrapped up by core rotation. This is an important result for disk formation theory, as it suggests that field misalignment may indeed be the solution to the magnetic braking catastrophe. Finally, we find that all sources exhibit the so-called "polarization hole" effect, where the polarization drops significantly near the total intensity peak. When this effect was seen in low-resolution single-dish maps, it was attributed to the averaging of unresolved structure in the plane of the sky. However, the higher resolution maps we present here resolve these twisted polarization morphologies, and yet the drop in fractional polarization persists, suggesting that fields are twisted along the line of sight, or that grain alignment is poor in dense regions with high extinction and high collision rates.

215 – Stars - M & L Dwarfs
Oral Session – National Harbor 5 - 07 Jan 2014 10:00 am to 11:30 am

215.01 – The <i>CASTOFFS</i> Survey: Pursuit of Young M Dwarfs Adrift in the Solar Neighborhood

Joshua E. Schlieder[1], Mickael Bonnefoy[7, 1], Niall Deacon[1], Tom Herbst[1], Katharine Johnston[1], Sebastien Lepine[2, 3], Johan Olofsson[1], Emily L. Rice[4, 3], Edo Berger[5], Andrew Skemer[6], Philip Hinz[6], Gael Chauvin[7], Carolina Bergfors[8], Thomas Henning[1], Eric Gaidos[9]
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The census of young, M dwarfs in the solar neighborhood is incomplete. Many constituents of the known sample are members of nearby, young moving groups (NYMGs), loose associations of coeval stars with common Galactic kinematics. Thus, new candidates of the under-sampled low-mass star population can be found via their possible association with NYMGs. We have therefore launched the **C**ool **A**strometrically **S**elected **T**argets **O**ptimal **F**or **F**ollow-up **S**pectroscopy (*CASTOFFS*) survey to identify and characterize previously unrecognized young, low-mass stars. We combine astrometry, photometry, and activity to find candidates and use dedicated spectroscopic follow-up to verify their youth. We are now 1.5 years into *CASTOFFS* and present early results to highlight new discoveries and provide a taste of what's to come. These results include two low-mass multiple systems: the first, a young hierarchical triple where the primary hosts a candidate debris disk, the other, a 1 AU separation, ?100 Myr old, late-M binary. We also briefly introduce likely new members of NYMGs that represent key targets for further follow-up.

215.02 – Kepler's Cool Eclipsing Binaries

Jonathan Swift[1], Philip S. Muirhead[2], John A. Johnson[3], Alexandria Gonzales[4], Avi Shporer[1], Peter Plavchan[5], Alex Lockwood[1], Tim Morton[6]
1. Caltech, Pasadena, CA, United States. 2. Boston University, Boston, MA, United States. 3. Harvard, Cambridge, MA, United States. 4. Scripps College, Claremont, CA, United States. 5. IPAC, Pasadena, CA, United States. 6. Princeton, Princeton, NJ, United States.

Some of the most exciting exoplanet results to date have come from the smallest and coolest sample of stars in the Kepler field—the M dwarfs. These cool stars represent the largest stellar population in the Galaxy which in turn harbors one of the largest known exoplanet populations. However, an accurate understanding of their physical properties currently eludes us. Detached, M dwarf eclipsing binary systems provide an accurate and precise, model-independent means of measuring the fundamental properties of low-mass stars shedding light on the rich physics embodied by this spectral class and refining our knowledge of their exoplanets. We have undertaken an observational campaign to obtain masses, radii, and effective temperatures of the Kepler eclipsing binaries having an M dwarf primary with periods between 1 and 60 days. These data will allow detailed comparisons between stellar properties, binary period, rotation, metallicity and activity levels.

215.03 – HAZMAT I: The Evolution of Far- and Near-UV Emission from Early M Stars

Evgenya Shkolnik[1], Travis S. Barman[2], Sarah Peacock[2]
1. Lowell Observatory, Flagstaff, AZ, United States. 2. University of Arizona, Tucson, AZ, United States.

With the recent discoveries of several super-earths orbiting M dwarfs well within their habitable zones (0.1 to 0.4 AU), and with many more such planets to come, it is critical to assess the evolution of the high-energy radiation environment of these systems. We have begun the HAZMAT (Habitable Zones and M dwarf Activity across Time) program by first measuring the drop in near-UV and far-UV flux in early M stars from 10 Myr to several Gyr using photometry from NASA's Galaxy Evolution Explorer (GALEX). We focus this study on the confirmed low-mass members of nearby young moving groups, the Hyades cluster, and old field stars. We show a relatively slow decline in UV flux up until at least 650 Myr with a sharper drop in the old M dwarfs. Yet without confirmed M dwarfs in nearby star clusters with ages of 1-2 Gyr, mapping the precise evolution at these older ages is not currently possible. The UV data also provide much-needed constraints to M dwarf upper-atmosphere models, which are insufficient for predicting UV emission from M dwarfs. Our analysis will produce empirically-motivated chromospheric profiles for the young and old M stars, which can then be used to predict the extreme-UV fluxes most critical to the evolution of a planetary atmosphere. The HAZMAT program is the first comprehensive study of the UV history of M

stars, and will ultimately tell us if a planet in the canonical habitable zone can indeed be habitable.

215.04 – Gyrochronology of Low-mass Stars - Age-Rotation-Activity Relations for Young M Dwarfs

Benjamin Kidder[1], Evgenya Shkolnik[2], Brian Skiff[2]
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New rotation periods for 34 young (~<300 Myr), early-M dwarfs within 25 parsecs were measured using photometric data collected with telescopes at Lowell Observatory during 2012 and 2013. An additional 25 rotation periods for members of the same sample were found in the literature. Ages were derived from Hα and X-ray emission, lithium absorption, surface gravity, and kinematic association of members of known young moving groups (YMGs). We compared rotation periods with the estimated ages as well as indicators of magnetic activity, with the intention of strengthening age-rotation-activity relations and assessing the possible use of gyrochronology in young, low-mass stars. We compared ages and rotation periods of our target stars to cluster members spanning 1-600 Myr. Rotation periods at every age exhibit a large scatter, with values typically ranging from 0.2 to 15 days. This suggests that gyrochronology for individual field stars will not be possible without a better understanding of the underlying mechanisms that govern angular momentum evolution. Yet, on average, the data still support the predicted trends for spin-up during contraction and spin-down on the main sequence, with the turnover occurring at around 150 Myr for early Ms. This suggests that rotation period distributions can be helpful in evaluating the ages of coeval groups of stars. Many thanks to the National Science Foundation for their support through the Research Experience for Undergraduates Grant AST- 1004107.

215.05 – The SDSS-III APOGEE Radial Velocity Survey of M Dwarfs

Rohit Deshpande[1], Chad F. Bender[1], Suvrath Mahadevan[1], C. H. Blake[2], R. C. Terrien[1], Joleen K. Carlberg[3], Gail Zasowski[4], Justin R. Crepp[5]
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Contributing teams: APOGEE M dwarfs

We are carrying out a large ancillary program within the Sloan Digital Sky Survey III (SDSS-III) using the fiber-fed, multi-object, near-infrared spectrograph built for the Apache Point Observatory Galactic Evolution Experiment (APOGEE) to obtain high resolution, H-band spectra of more than 1200 M dwarfs. These observations will be used to measure spectroscopic rotational velocities, radial velocities, physical stellar parameters, metallicity, and variability of the target stars. This survey significantly increases the number of M dwarfs studied for rotational velocities (at precision of $\sim$2 km/s and a measurement floor at 4 km/s), and radial velocity variability (at $\sim$100-200 m/s). This survey will inform and advance the target selection for planned radial velocity and photometric searches for low mass exoplanets around M dwarfs, such as HPF, CARMENES, and TESS. In this talk, I will describe the target selection for this survey, as well as results from the first year of scientific observations based on spectra that are publicly available in the SDSS-III Data Release 10 (DR10). Furthermore, I will discuss orbital parameters and mass ratios of M dwarf binaries discovered in the first year of the data.

215.06 – Empirical Estimates of Fundamental Properties for Nearby M Dwarfs Based on Near Infrared Spectra

Elisabeth R. Newton[1], David Charbonneau[1], Jonathan Irwin[1], Zachory K. Berta-Thompson[2, 1], Barbara D. Rojas Ayala[3], Kevin Covey[5], James P. Lloyd[4]
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We present estimates of the fundamental properties for 447 nearby M dwarfs using empirically-derived relationships based on the strengths of near infrared spectral features. We obtained our moderate resolution (R=2000) spectra with IRTF/SpeX. Our stars are targets of the MEarth Survey, a transiting planet survey searching for super Earths around mid-to-late M dwarfs within 33pc. We establish our relationships for radius and temperature using M dwarfs with interferometric measurements, and find that our relations have an accuracy of 0.04 solar radii and 60 K for M0-M4 dwarfs. To calibrate our relationship for [Fe/H], we use M dwarfs in common proper motion pairs with more massive stars of known metallicity. Our metallicity relation has an accuracy of 0.12 dex and is valid for NIR spectral types from M1V-M5V and for -1.0<[Fe/H]<+0.35 dex. We also present spectroscopic distance estimates and radial velocities for our targets. Our distances are estimated from new calibrations that use either NIR spectral type or an index based on the curvature of the K-band continuum and are

accurate to 14%. We measure radial velocities by modeling telluric features to determine the absolute wavelength calibration for our spectra, and we demonstrate an accuracy of 4 km/s by considering M dwarfs with previously published radial velocities, M-dwarf binaries, and multi-epoch observations.

215.07 – Discovery of a Benchmark, Extremely-Red, Young L Dwarf

Katelyn N. Allers[1], Michael C. Liu[2], Michael C. Kotson[2], Eugene A. Magnier[2], Niall Deacon[3], Trent J. Dupuy[4], Kimberly M. Aller[2]
1. Bucknell University, Lewisburg, PA, United States. 2. Institute for Astronomy, University of Hawai'i, Honolulu, HI, United States. 3. Max Planck Institute for Astronomy, Heidelberg, Germany. 4. Harvard-Smithsonian Center for Astrophysics, Boston, MA, United States.

We have discovered a nearby (24.6 pc) extremely red (J-K=2.84) late-L dwarf. PSO J318.5-22 is the first free-floating object that is truly an exoplanet analog, as it has colors, spectra and luminosity that are remarkably similar to the directly imaged exoplanets around HR 8799 and 2MASS J1207. Its position and tangential velocity point to membership in the ~12 Myr old beta Pictoris moving group, which implies a very low mass (~6.5 M_Jupiter). Overall, PSO J318.5-22 provides an interesting analog to young, dusty exoplanets in a context where detailed study of the atmospheric dust/cloud properties is possible. Using moderate-resolution near-IR spectroscopy, we classify PSO J318.5-22 as a young L7 dwarf. We compare PSO J318.5-22 to the spectra of other known, incredibly red objects and find unexpected spectral diversity for objects having similar colors and luminosities. We determine the effective temperatures inferred by the spectral types, atmospheric models, and luminosities of extremely red objects with parallax measurements. At a given spectral type, we find that extremely red, young L dwarfs are cooler than field objects. The temperatures inferred by atmospheric models lead to physically implausible radii, similar to the discord seen in model atmosphere fits of young, dusty planets.

216 – Supernovae & Nebulae I
Oral Session – National Harbor 2 – 07 Jan 2014 10:00 am to 11:30 am

216.01 – Type IIP supernova progenitor properties from Pan-STARRS1 light curves

Nathan Sanders[1], Alicia M. Soderberg[1]
1. Harvard University, Cambridge, MA, United States.
Contributing teams: Pan-STARRS1 CfA Supernova Group

We discuss a comprehensive and uniform analysis of the light curves of more than 100 spectroscopically-confirmed Type II supernovae discovered by the Pan-STARRS1 (PS1) survey. Our sample is drawn from more than 4 years of multi-band optical/NIR (grizy) imaging from the PS1 Medium-Deep Survey (MDS). We have developed and applied a Bayesian methodology for modeling the supernova light curves. This framework robustly models available data and produces constraints on the full, multiwavelength evolution of each object in the sample, even when observations are sparse or coverage is limited. We focus on the most common class of massive star explosion, Type IIP supernovae, with a typical redshift of z = 0.1 in our sample. Utilizing the deep imaging, high cadence (1-2 day), and long survey duration of the PS1 MDS, we test for variation in the rise time behavior, plateau duration, and temperature evolution of the supernovae. We discuss inferences on the distribution of progenitor star and explosion properties (mass, radius, and energy) permitted by these measurements, and their implications for our understanding of the death processes of massive stars in the local universe.

216.02D – The UV Properties of Core Collapse Supernovae

Tyler A. Pritchard[1], Peter Roming[2, 1]
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With the advent of robotic telescope transient surveys in the 1990's, the study of Supernovae (SNe) in the optical and infrared wavelengths underwent a revolution as the number of SNe discovered per year increased by well over an order of magnitude in the ensuing decade. UV studies of these objects lagged behind their optical/NIR counterparts, however, due to a limited observing capability. With the launch of Swift in 2005 a similar revolution took place in the UV as it was finally possible to regularly obtain well-sampled UV and optical observations with the Swift UV/Optical Telescope (UVOT; λc = 1928, 2246, 2600 Å). In 2007 Swift/UVOT observed SN 2007pk, which was at the time the earliest observed Type IIn SNe in the UV, and whose study led us to understand the need for a more comprehensive sampling of Core Collapse Supernovae (CCSNe) observations than had previously been performed. Using data from Swift's launch to the end of 2012, we produce a study of the UV characteristics of CCSNe, dependant upon SNe subtype. We find that at early times or around peak magnitude, contingent upon subtype, a majority of the supernovae flux can occur in the UV regime. However, due to ground based observing constraints this flux often goes unmeasured. This missing flux, and associated corrections, has implications for SNe explosion models which use bolometric light curves to examine factors including: supernovae explosion energy, progenitor radius, CSM winds, and metallicity. We then calculate bolometric light curves for this sample of CCSNe, along with empirical UV-corrections from these for bolometric light curves that have been generated without UV data. We then refine these corrections using a smaller sample of Type IIP SNe from the Carnegie Supernovae Project that overlap with Swift observations, resulting in bolometric light curves with a comprehensive UV-NIR coverage. Finally, using recent numerical simulations we compare variations in observed model light curves due to progenitor differences with observed UV data. Support for this work is sponsored at PSU and SwRI by the NASA ADP grant NNX12AE21G.

216.03 – Core Collapse Supernova Models For Nucleosynthesis

Jordi Casanova[1], Carla Frohlich[1], Albino Perego[3], Matthias Hempel[2]
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Type II supernova explosions are the product of the collapse of massive stars (M > 8-10 Msun), which explode with a kinetic energy release of 1e51 erg. While sophisticated multi-dimensional models can reveal details of the explosion mechanism (role of convection, fluid instabilities, etc.), they are computationally too expensive for nucleosynthesis studies. However, precise nucleosynthesis predictions are needed to understand the supernova contribution to the heavy elements and the abundances observed in metal-poor stars. We have modeled the core collapse, bounce and subsequent explosion of massive stars assuming spherical symmetry with the code Agile-IDSA (Liebendoerfer et al. 2009) combined with a novel method to artificially trigger the explosion (PUSH). The code also includes the Hempel EOS, which uses a modern non-NSE to cover the entire nucleosynthesis duration. In our simulations, based on the neutrino-delayed explosion mechanism, the explosion sets in by depositing a small amount of additional energy (from mu and tau neutrinos) to revive the stalled shock. Our results show that the code Agile-IDSA combined with PUSH is very robust and can successfully reproduce an explosion with a more reliable treatment of the crucial quantities involved in nucleosynthesis (i.e., the electron fraction). Here, we present a

detailed isotopic abundance study for a wide variety of progenitors, as well as an analysis of the explosion properties, such as the explosion energies, remnant masses or compactness of the progenitor models.

216.04 – Multidimensional Radiation Hydrodynamic Simulations of Core-Collapse Supernovae

Joshua Dolence[1], Adam S. Burrows[1], Weiqun Zhang[2]
1. Princeton University, Princeton, NJ, United States. 2. Lawrence Berkeley National Laboratory, Berkeley, CA, United States.

The mechanism underlying core-collapse supernova explosions remains poorly understood. I will present recent results of multidimensional neutrino radiation hydrodynamic simulations for a variety of progenitors and describe how our results fit into the broader context of state-of-the-art modeling by groups around the world.

216.05 – Revival of The Stalled Core-Collapse Supernova Shock Triggered by Precollapse Asphericity in the Progenitor Star

Sean M. Couch[1], Christian D. Ott[2]
1. University of Chicago, Chicago, IL, United States. 2. Caltech, Pasadena, CA, United States.

Multi-dimensional simulations of advanced nuclear burning stages of massive stars suggest that the Si/O layers of presupernova stars harbor large deviations from the spherical symmetry typically assumed for presupernova stellar structure. We carry out three-dimensional core-collapse supernova simulations with and without aspherical velocity perturbations to assess their potential impact on the supernova hydrodynamics in the stalled shock phase. Our results show that realistic perturbations can qualitatively alter the postbounce evolution, triggering an explosion in a model that fails to explode without them. This finding underlines the need for a multi-dimensional treatment of the presupernova stage of stellar evolution.

216.06 – Core Collapse or Thermonuclear? New Evidence for the Ambiguous Cases of SNe 2005gj and 2012ca

Ori D. Fox[1]
1. UC Berkeley, Berkeley, CA, United States.

A growing number of Type Ia supernovae show evidence for interaction with the surrounding circumstellar medium (SNe Ia-CSM). Despite the Type Ia classification, the ambiguous nature of the spectra raises the question of whether these SNe are thermonuclear or core-collapse in origin. Here I present multi-wavelength observations (X-ray to Radio) of SN 2012ca and mid-infrared observations of SN 2005gj, two well-studied objects in this subclass. These observations probe both the ongoing shock interaction and the CSM characteristics/geometry. I will discuss these new clues in the context of the SN progenitor system and the origin of the dense CSM.

216.07 – Host Galaxies of High Ejecta-Velocity Core-Collapse Explosions

Patrick Kelly[1]
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In the cases of a growing number of long-duration gamma-ray bursts (LGRBs), a coincident broad-lined Type Ic supernova (SN Ic-BL) superimposed on the power-law continuum of the fading optical afterglow has been detected. SN Ic-BL show wide spectroscopic features that are consistent with high ejecta velocities of ~30,000 km/s, while all other core-collapse SN are inferred to have more slowly expanding ejecta. I will discuss the properties of the host galaxies of core-collapse explosions with high ejecta velocities and implications for their massive progenitor populations.

217 – Surveys and Large Programs I
Oral Session – Maryland Ballroom D – 07 Jan 2014 10:00 am to 11:30 am

217.01 – LEGUS: A Legacy ExtraGalactic UV Survey of Nearby Galaxies with HST

Janice C. Lee[1, 20], Daniela Calzetti[2], Angela Adamo[3], Alessandra Aloisi[1], Jennifer E. Andrews[2], Thomas M. Brown[1], Rupali Chandar[4], Carol A. Christian[1], Michele Cignoni[5], Geoffrey C. Clayton[6], Robert L. Da Silva[7], Selma E. de Mink[10], Claire Dobbs[8], Bruce Elmegreen[9], Debra M. Elmegreen[11], Aaron S. Evans[12], Michele Fumagalli[10], John S. Gallagher[13], Dimitrios Gouliermis[3], Eva Grebel[14], Artemio Herrero-Davo`[15], Bryan Hilbert[1], Deidre A. Hunter[16], Kelsey E. Johnson[12], Robert Kennicutt[17], Hwihyun Kim[18], Mark R. Krumholz[7], Danny J. Lennon[19], Christopher D. Martin[20], Preethi Nair[1], Antonella Nota[22], Anne Pellerin[21], Jose Prieto[29], Michael W. Regan[1], Elena Sabbi[22], Daniel Schaerer[23], David Schiminovich[24], Linda J. Smith[22], David A. Thilker[25], Monica Tosi[26], Schuyler D. Van Dyk[20], Rene A. Walterbos[27], Bradley C. Whitmore[1], Aida Wofford[28]
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We introduce LEGUS, a Hubble Space Telescope program which will provide a critical missing piece in our efforts to solve the star formation puzzle: a robust characterization of the links between star formation on two fundamental scales, those of individual young stars, stellar clusters and associations over parsec scales, and of galaxy disks over kiloparsec scales. As a 154-orbit Treasury survey, LEGUS has begun obtaining NUV,U,B,V,I imaging of 50 star-forming galaxies, at distances of 4-12 Mpc. The dataset is guaranteed to have exceptional legacy value, as the targets have been carefully selected to uniformly sample a full range of global galaxy properties, as well as have the largest suites of multi-wavelength ancillary data available. The high-resolution HST NUV and U imaging are key for deriving accurate recent (<50 Myr) star formation histories from resolved massive stars, along with the ages and masses for complete samples of star clusters and associations in each galaxy. We present an overview of the sample, the observations, and provide a first look at the science that the LEGUS team is pursuing. A companion poster presents the status of the program, and a more detailed description of the extensive data products being developed which will seed community science, and provide a foundation for studies of star formation with ALMA and JWST.

217.02 – Improved spectral energy distribution fitting of galaxies at 1 < z <3.5 in the SFR-M* plane and their morphological properties

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Contributing teams: The CANDELS collaboration

In the star formation rate (SFR) - stellar mass (M*) diagram, galaxies can be separated in four different populations: starbursts which lie above the main sequence of star formation (MS), normal star-forming galaxies on the tight MS, galaxies below the MS with a little star-forming activity and quiescent galaxies. Renzini (2009) suggested that galaxies on, above and below the MS follow very different time evolution of SFR. We test this idea with large samples of galaxies at 1 < z < 3.5 selected from the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS) in the GOODS-North and South fields. Thanks to an improved SED fitting technique, which should yield more accurate stellar mass, we investigate if there are systematic variations of past star formation histories (SFH) for galaxies in the four different populations. We further

study correlations and trends between the morphology of the galaxies and their positions relative to the MS using non-parametric (Sersic index) and parametric measures as well as the visual identification. We also explore the effects on the rest-frame colors of dust obscuration to constrain the slope and the scatter on the MS.

217.03 – Herschel-CANDELS: The Infrared Luminosity Function and its Evolution

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Contributing teams: CANDELS+Herschel Team, The CANDELS collaboration

We will show new results from the Herschel deep imaging observations of the cosmological survey field from the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS). The deep Herschel data were taken in the GOODS-S, -N, COSMOS, and UDS fields, which provide good statistics and control over cosmic variance. We will present the infrared luminosity functions derived from the Herschel data in these four CANDELS fields, and discuss their evolution.

217.04D – The formation of the compact early-type galaxies at high-redshift

Christina C. Williams[1], Mauro Giavalisco[1]
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Contributing teams: The CANDELS Collaboration

The first galaxies in the universe (e.g. z>2) to quench their star-formation appear to be both the most massive, and also the most compact (in stellar density). The nature of quenching mechanisms are poorly understood at any epoch, however the ubiquity of these quenched compact galaxies at high-redshift implies that quenching at this epoch, during the peak of star-formation activity in the universe, preferentially affects compact galaxies. We have selected a sample of their star-forming progenitors among Lyman-Break Galaxies (LBGs) at z~3 based on the hypothesis that any candidate progenitors must also be compact, since merging and accretion tend to increase the sizes of galaxies. We present results based on analysis of both the spectral energy distributions and available spectroscopy for these compact star-forming progenitors compared to ordinary (in size) LBGs of similar masses. We find that these compact progenitors have redder rest-frame ultra-violet colors than ordinary LBGs, but with similar optical colors, consistent with an older burst of star-formation. Using rest-frame ultra-violet spectroscopy, we also find the compact progenitors have higher metallicities and/or more powerful winds than ordinary LBGs. These results are consistent with the idea that these compact galaxies evolve faster and quench earlier in cosmic time than more ordinary LBGs of similar mass. Ongoing analysis of these winds in compact galaxies, including additional spectroscopy, will provide crucial insight into the physics of quenching in galaxies.

217.05 – Live fast, die small: compact SFGs at z=2-3, the building blocks of the red-sequence

Guillermo Barro[1], Sandra M. Faber[1], Pablo Perez-Gonzalez[2], Camilla Pacifici[3], Jonathan R. Trump[1], David C. Koo[1], Yicheng Guo[1]
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Contributing teams: The CANDELS collaboration

The mechanisms responsible for the remarkably small sizes of quiescent galaxies at z~2 are poorly understood. Partly because the nature of their progenitors is still unknown. In Barro et al. 2013, we used the deepest CANDELS WFC3/F160W data to identify, for the first time, a population of compact star-forming galaxies (cSFGs) at 2 < z < 3, whose structural properties and number densities suggest that they could be the progenitors of such population. Now we present a detailed analysis of 45 massive (log(M)>10) cSFGs to verify that hypothesis. We find that cSFGs present heavily obscured star-formation, evidenced by their colors in the optical/NIR (UVJ) and far-IR (with 71% and 44% detected in Spitzer/MIPS and Herschel/PACS. Structurally, they present smooth spheroidal morphologies, high Sersic indices (n>3), and centrally-concentrated mass profiles similar to those of quiescent galaxies, but strikingly different from other massive SFGs which are typically disky (n<2), and sometimes clumpy or irregular. The majority of compact SFGs are either on the main-sequence (62%) or below it (33%), in agreement with the notion that they are on an evolutionary path towards the red sequence. Using a novel approach, we analyze the stellar populations of these galaxies using physically motivated star-formation histories (SFHs) drawn from semianalytic models (SAMs) of galaxy formation. Overall, we find that these galaxies are in intermediate-to-late evolutionary stages, with ages ranging between t = 1.6 - 2.3 Gyr. This implies they began to form at redshifts as high as z = 5 - 6. We also find that the least massive galaxies have shorter formation histories, contrary to the usual downsizing intuition. Finally, we compare possible formation scenarios for compact SFGs in the context of recent SAMs and hydrodynamic simulations. In both cases, gas-rich disk instabilities (DI) in more extended SFGs appear to be the dominant mechanism. DIs cause a rapid gas infall, building up a central mass density, and reducing the effective radii of the galaxy by up to a factor of 2 in timescales of a few hundred Myr.

217.06 – Are Compton-Thick AGN the Missing Link Between Mergers and Black Hole Growth?

Dale Kocevski[1], Kirpal Nandra[2], Murray Brightman[2]
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Contributing teams: The CANDELS Collaboration

Galaxy mergers have long been proposed as a possible triggering mechanism for AGN activity, but surveys of X-ray selected AGN out to z~2 have consistently failed to find morphological signatures of recent merger activity. A major caveat to these results is that most past studies have not been sensitive to heavily obscured, Compton-thick AGN. Hydrodynamical merger simulations predict that this obscured phase should coincide with the most morphologically disturbed phase of a galaxy interaction. Using high-resolution HST/ACS imaging, we have examined the morphologies of a sample of 120 compton-thick AGN at z<1.5 identified by their reflection-dominated X-ray spectra. We find evidence for a statistically significant excess of disturbed morphologies among these heavily obscured AGN compared to unobscured AGN with similar X-ray luminosities. I will discuss the implications of these results for the Unified Model and the possibility that the AGN-merger connection has been systematically missed in the past due to poor sampling of the obscured AGN population.

217.07 – The Mass Function of the First Galaxies from the CANDELS Survey

Christopher Conselice[1], Kenneth Duncan[1], William Hartley[1], Alice Mortlock[1]
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Contributing teams: The CANDELS collaboration

Observations of the galaxy stellar mass function (SMF) provide important constraints on galaxy evolution at high redshifts as they are a fundamental characteristic of the galaxy population. As such, we have used the extensive multi-wavelength observations from the CANDELS GOODS-S field to generate robust samples of galaxies at z ~ 4 - 7. This is the largest sample of high redshift galaxies in which the stellar mass function has yet been measured. For these samples we use extensive spectral energy distribution fitting to derive stellar masses, exploring the effects of including optical emission lines in the fitting on the derived stellar masses and their resulting mass functions. We will present the results of this work, showing how the shape of the SMF evolves during the first billion years of galaxy evolution.

217.08 – NEOWISE: A Mid-Infrared Synoptic Survey

Amanda K. Mainzer[1], James M. Bauer[1, 2], Roc M. Cutri[2], Tommy Grav[3], Joseph R. Masiero[1], Edward L. Wright[4], Carolyn Nugent[1], Rachel Stevenson[1], Beth Fabinsky[1]
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NASA's Wide-field Infrared Survey Explorer surveyed the entire sky in four infrared wavelengths (3.4, 4.6, 12 and 22 microns) over the course of one year. The mission's long wavelength infrared channels were cooled by solid hydrogen; after its depletion, the mission continued using the two shortest wavelengths. Following completion of its one year survey, the mission was placed into hibernation. NASA has recently enabled the restart of the mission to discover, detect and characterize near-Earth objects (NEOs) using the 3.4 and 4.6 micron channels. With these wavelengths, it is possible to derive radiometric effective spherical diameters for NEOs with ~25% accuracy. In the process of surveying for NEOs over three years, NEOWISE will cover the sky multiple times, enabling a wide range of scientific investigations.

218 – The Solar System
Oral Session – Potomac Ballroom D – 07 Jan 2014 10:00 am to 11:30 am

218.01 – Saturn's Ring Rain: Water Influx and Ring Lifetime Estimates

Luke Moore[1], James O'Donoghue[2], Ingo Mueller-Wodarg[3], Michael Mendillo[1]
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We estimate rates of mass loss from Saturn's rings based on ionospheric model reproductions of derived H3+ column densities. On 17 April 2011 over two hours of near-infrared spectral data were obtained of Saturn using the Near InfraRed Spectrograph (NIRSPEC) instrument on the 10-m Keck II telescope. The intensity of two bright H3+ rotational-vibrational emission lines was visible from nearly pole to pole, allowing low-latitude ionospheric emissions to be studied for the first time, and revealing significant latitudinal structure, with local extrema in one hemisphere being mirrored at magnetically conjugate latitudes in the opposite hemisphere. Furthermore, those minima and maxima mapped to latitudes of increased or increased density in Saturn's rings, implying a direct ring-atmosphere connection in which charged water group particles from the rings are guided by magnetic field lines as they "rain" down upon the atmosphere. Water products act to quench the local ionosphere, and therefore modify the observed H3+ densities. Using the Saturn Thermosphere Ionosphere Model (STIM), a 3-D model of Saturn's upper atmosphere, we derive the rates of water influx required from the rings in order to reproduce the observed H3+ emissions. As a unique pair of conjugate latitudes map to a specific radial distance in the ring plane, the derived water influxes can equivalently be described as rates of ring mass erosion as a function of radial distance in the ring plane, and therefore also allow for an improved estimate of the lifetime of Saturn's rings.

218.02 – New Studies of Jovian Decametric Emission using the Long Wavelength Array Station 1

Tracy E. Clarke[1], Jinhie Skarda[2], Charles Higgins[3], Kazumasa Imai[4], Masafumi Imai[5], Francisco J. Reyes[6]
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Contributing teams: Long Wavelength Array

Jovian decametric emission produced through the cyclotron maser instability can be observed using ground-based radio instruments sensitive in the frequency range of 10 - 40 MHz, the lower limit being set by the ionospheric cutoff. We present an overview of new results from observations of Io-controlled emission using the newly commissioning Long Wavelength Array Station One (LWA1). This new and powerful interferometer is capable of observing between 10 and 88 MHz with up to four simultaneous independently steerable beams on the sky. Each beam can be tuned to two separate frequencies with bandwidths of up to 19.6 MHz and the output of each tunings contains dual orthogonal polarizations. We present observations of several Io-A/Io-C bursts which highlight the apparent early start of the Io-C emission at low frequencies. We also find clear evidence of Io-D emission during and after Io-B bursts. The sensitivity of the LWA1 allows us to undertake a detailed study of fine structure during the Io-D event such as S-burst drift rates. Basic research in Radio Astronomy at the Naval Research Laboratory is funded by 6.1 Base funding. The LWA1 is supported by the National Science Foundation under grant AST-1139974 of the University Radio Observatory program.

218.03 – Fine Structure in Jupiter's Decametric Emission using the Long Wavelength Array Station 1

Charles Higgins[1], Tracy E. Clarke[2], Jinhie Skarda[3], Kazumasa Imai[4], Masafumi Imai[5], Francisco J. Reyes[6]
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Recent observations of Jupiter's decametric radio emissions were made with the LWA1 instrument and provide excellent spectral resolution over the bandwidth of 10 - 40 MHz. Using the full Stokes capabilities of LWA1, we show excellent detail of many well-known decametric features in Jupiter's spectrum (nested arc structure, modulation lanes, S-bursts, and N-events). The nested arc-structures result from the geometry of the hollow emission cone(s) and the observer as Jupiter rotates. Modulation lanes seen in many Jupiter events are caused by interference as the waves propagate through the field-aligned columns of enhanced or depleted plasma density located along the longitudinal direction near Io's orbit (Imai et al., 2002).

LWA1 data showing simultaneous modulation lanes in both polarizations for a Jupiter Io-C event suggest that both polarizations might be coming from the same hemisphere, contrary to the emission theory. Jupiter also emits millisecond S-bursts which are the strongest of the Jovian Io-controlled decametric emission (> 10 MJy). These bursts are concentrated in the bandwidth of 18 – 33 MHz and show very complex structures such as frequency drifting, source splitting, and combination. The S-burst frequency drift rates are similar to previous measurements and suggest that electrons are moving up the magnetic field lines away from the magnetic poles. Observations of some S-bursts show an interaction with narrow-band (N) events, by either triggering or quenching the resonance set up in the source emission zone. Further analyses are needed to understand this mechanism and other features of Jupiter's decametric spectrum. We show many Jupiter spectra and highlight the new capabilities of the LWA1 telescope.

218.04 – Trojan Asteroid Lightcurves from the Palomar Transient Factory Survey

Adam Waszczak[1], Eran Ofek[2]
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Contributing teams: PTF Team

The orbital and physical properties of Jupiter's Trojan asteroids constrain models of their origin and our solar system's broader dynamical history. Studies of the Trojans' two main compositional classes (the C-type and D-type taxonomic groups) have heretofore been based primarily on spectra or multi-band photometry. However, many of the wide-field surveys that contribute Trojan observations obtain only single-band or unfiltered data, though often with good temporal coverage. In this work we test the feasibility of classifying Trojans and characterizing their surface properties using lightcurves, with particular emphasis on the phase-function component. For a sample of 45 large Trojans (D>20 km) observed serendipitously by the Palomar Transient Factory survey, we fit a multi-parameter rotational plus single-parameter (constant slope) phase-function model to each object. We find a narrow distribution of fitted phase slopes (0.04 to 0.06 mag/deg), and examine the extent to which the two Trojan taxonomic types are distinguishable within this phase-slope distribution. We also investigate a possible correlation in phase-function behavior with orbital inclination.

218.05D – A dynamical model for the impact rate and angular distribution of long period comets

Fabo Feng[1], Coryn Bailer-Jones[1]
1. MPIA, Heidelberg, Germany.

The cratering record on the Earth and Moon shows that our planet has been exposed to high velocity impacts for much or all of its existence. Some of these craters are generated by the impact of long period comets (LPCs). These probably originated in the Oort cloud, and were put into their present orbits through gravitational perturbations arising from the Galactic tide and stellar encounters, both of which are modulated by the solar motion about the Galaxy. We have constructed a dynamical model to describe both the variable impact rate of LPCs and the angular distribution of their perihelia (which is observed to be non-uniform). Comparing the predictions of this model with other models, we find that the dynamical model is marginally favored as an explanation for the terrestrial cratering record. Unlike the hypothesis of a massive body in the outer Oort Cloud, our dynamical model predicts a non-uniform angular distribution of the perihelia as a consequence of the solar apex motion. Our results are reasonably robust to changes in the parameters of the Galaxy model, Oort cloud, and stellar encounters.

218.06 – The Characteristics and Evolution of the Dust Coma of Comet C/2012 S1 (ISON)

Jian-Yang Li[1], Michael S. Kelley[2], Matthew M. Knight[3, 4], Tony Farnham[2], Harold A. Weaver[4], Michael F. A'Hearn[2], Maximilian J. Mutchler[5], Ludmilla Kolokolova[2], Philippe L. Lamy[6], Imre Toth[7], Karen Xia[8]
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C/2012 S1 (ISON) is a dynamically new comet with a sungrazing perihelion only 1.7 solar radii from the Sun's surface, which makes it unique among the known comets. The discovery of C/ISON in September 2012 at a heliocentric distance of ~6 AU is more than one year before its perihelion in November 2013, allowing a detailed characterization as the comet moves from

the frigid conditions of the outer solar system to extreme heating during its close passage near the Sun. As part of an international observing campaign, the Hubble Space Telescope (HST) imaged the comet in multiple epochs from April to October 2013 pre-perihelion to characterize its dust coma at 4.15, 3.78, and 1.50 AU. We report on our analysis of these HST images, including the dust production rate, the dust coma colors and morphology, and the rotation pole of the nucleus. The first two epochs of observations showed that C/ISON displays a color variations in its dust coma within ~5000 km from the nucleus that is best explained by the existence and sublimation of water ice grains. The pole orientation, as measured from the sunward jet, suggests a high obliquity, and indicates that the nucleus of C/ISON always faces the Sun with one hemisphere until about a week before the perihelion. We will use the observations in October to search for any evolutionary changes in the coma, and to refine the determination of the rotation pole.

218.07 – Linear Polarization Measurements of Comet Lovejoy from STEREO and SOHO, and their Application to Comet ISON

William T. Thompson[1], Karl Battams[2]
1. Adnet Systems, Inc., Lanham, MD, United States. 2. Naval Research Laboratory, Washington, DC, United States.

The Kreutz sungrazing comet C/2011 W3 (Lovejoy) passed within 140,000 km of the solar surface on 16 December 2011. It has the distinction of being the first sungrazing comet observed from space known to survive perihelion passage. During both the inbound and outbound passages, it was well observed by the coronagraphs aboard the Solar and Heliospheric Observatory (SOHO) and the twin Solar and Terrestrial Relations Observatory (STEREO) spacecraft. The combination of the three different viewpoints covers a large range of polarization phase angle curve. Extremely large polarization levels were measured for Comet Lovejoy, ranging from about -15% in the negative branch at low phase angles, to as much as 60% or more in the positive branch. To the best of our knowledge, these high polarization levels are completely unprecedented. The negative branch extends to larger phase angles than usual, with the highest level of negative polarization occuring around 35 degrees, and the transition from negative to positive occuring around 45-50 degrees. Stratification along the tail was also detected, with the degree of polarization increasing with greater distance from the nucleus. This is interpreted as a stratification of particle sizes, with larger more amorphous particles near the comet head, and smaller more spherical particles farther back in the tail. Results from Comet Lovejoy are being used to guide the observational plan and analysis of Comet ISON. The same three spacecraft will observe Comet ISON during the days surrounding its perihelion passage on 28 November 2013, and preliminary results from these observations will be presented.

218.08 – Modeling Results for Optically Thick Deep Impact Spectra

Alan Gersch[1], Michael F. A'Hearn[1], Lori M. Feaga[1]
1. Univ. of Maryland, College Park, MD, United States.

The great success of the Deep Impact Flyby spacecraft's cometary observations has occasioned the need for accurate interpretation of spectra with high spatial and spectral resolution very near comet nuclei. This requires using computational modeling of cometary spectroscopy. However, these spectra are of optically thick regions of the coma and determining accurate molecular abundances is a difficult problem. We have adapted Coupled Escape Probability, an exact method of radiative transfer, to solve this problem. Originally conceived for plane parallel situations, we have adapted and implemented the method for use in asymmetrical spherical geometries, thus enabling the modeling of coma morphology along with radiative transfer, to better understand Deep Impact observations. We present our best-fit models of Deep Impact data for CO_2 and H_2O spectra that account for optical depth effects in order to better understand the abundances and distribution of these important volatiles.

219 – Cannon Award: Giant Planets in Dusty Disks
Plenary Session – Potomac Ballroom A – 07 Jan 2014 11:40 am to 12:30 pm

219.01 – Giant Planets in Dusty Disks

Sarah E. Dodson-Robinson[1,2], Erik Brugamyer[1], Jens Teiser[3]

1. University of Texas at Austin, Austin, TX, United States. 2. University of Delaware, Newark, DE, United States. 3. University of Duisburg-Essen, Duisburg & Essen, Ruhr, Germany.

Giant planet formation begins with the formation of a solid core that grows to 10 Earth masses or more. Solids in the protoplanetary disk are therefore essential raw ingredients for gas giant formation. Yet dust in the protoplanetary envelope can halt giant planet growth, as its high opacity inhibits contraction and slows gas accretion. This talk will explore the effects of solids on the planet formation process. I will present evidence for a mineralogical bottleneck in planet formation, in which the iron, silicon and magnesium abudnances in the disk control the probability of gas giant formation. I will then show how photophoresis--the migration of dust grains in the direction of light flux--can push grains out of the protoplanetary atmosphere, increasing the likelihood of giant planet formation.

220 – CSWA Demographics Survey 2013

Town Hall – National Harbor 12 – 07 Jan 2014 12:45 pm to 01:45 pm

The AAS Committee on the Status of Women in Astronomy (CSWA) has been conducting demographics surveys of major astronomy departments and divisions since 1992 to track the representation of women across the field. In 2013 we updated the survey for the first time in 10 years. This town hall will present the results of the demographics survey and invite discussion about the implications for policy in our field.

221 – NASA Town Hall

Town Hall – Potomac Ballroom A – 07 Jan 2014 12:45 pm to 01:45 pm

Senior representatives from NASA's Science Mission Directorate and Astrophysics Division will discuss NASA's science program and outlook. Topics will include the status of the research program, highlights of operating missions, NASA's response to the Astro2010 decadal survey, progress of missions in development, and anticipated opportunities for both non-flight basic research awards (grants) and flight mission investigations.

222 – Thirty Meter Telescope (TMT) Town Hall
Town Hall – Potomac Ballroom C – 07 Jan 2014 12:45 pm to 01:45 pm

The TMT design has been under development since 2003 and is now technically mature. With the completion of the Design Development Phase in March 2009, the project entered the Preconstruction Phase, and is ready to enter the Construction Phase at the Mauna Kea site in April 2014. In this town hall, the latest status of the TMT project will be presented. As well, TMT is continuing a new era in planning to develop a public-private partnership in TMT, with opportunities for all members (individuals and institutions) of the US astronomy community to become engaged and involved in TMT through a potential-partnership planning exercise with the NSF. Opportunities for the community include continued development of the TMT science case, the organization of the national and international scientific programs, planning for the first-light and next-generation instrumentation programs, planning for observatory operations, data access and archiving, and long-term international development of the Mauna Kea site. In summary, TMT is a telescope with a 30-meter, filled aperture primary mirror composed of 492 x 1.46-meter segments. Instruments and an adaptive optics (AO) system will be housed on two large, stable Nasmyth platforms. TMT will have a broad suite of capabilities ranging from wide-field, multi-object, seeing-based spectrometers to instruments that operation at the diffraction limit of the telescope behind a high-performance AO system. The TMT project is an international partnership involving Canada, the USA, Japan, China, and India. It represents a unique combination of technical, industrial, and scientific collaboration that benefits all partners. Sited near existing, complementary facilities on Mauna Kea in Hawaii, TMT will unite the Pacific Rim astronomical community about its vantage point, and will exclusively provide extremely-large telescope (ELT) access to the northern sky.

223 – AGN Theory and Techniques
Oral Session – National Harbor 11 – 07 Jan 2014 02:00 pm to 03:30 pm

223.01 – Advection-Dominated Black Hole Accretion: Two-Fluid Hydrodynamics, Particle Acceleration, and Outflows

Jason P. Lee[1], Peter A. Becker[1]
1. George Mason University, Fairfax, VA, United States.

Radio-loud black holes are more likely to exhibit strong, relativistic outflows than radio-quiet objects, and they also emit lower X-ray luminosities, implying low accretion rates and densities. The tenuous gas is unable to radiate efficiently, leading to advection-dominated flow. The combination of high temperature and low density in such disks makes them ideal sites for the Fermi acceleration of relativistic particles at standing shock waves. In this presentation, we investigate the possibility that the observed outflows in the radio-loud sources may be powered by the escape of the relativistic particles accelerated at a shock in the disk. The dynamical structure of the radio-loud disks considered here is analyzed using a self-consistent two-fluid model in which the pressure of the accelerated relativistic particles is included in the dynamical equations. The inclusion of particle pressure in this model is analogous to the two-fluid model of cosmic ray shock acceleration. The associated energy-space distribution of the relativistic particles in the disk is analyzed using a suitable transport equation. The model is applied to interpret the outflows observed in M87 and Sgr A*, and the associated disk structures and source parameters are compared with the results obtained in previous studies.

223.02 – Making Intermediate mass black holes around Supermassive black holes: like making Jupiters around stars.

Barry McKernan[1, 2], Saavik Ford[1, 2], Bence Kocsis[3], Wladimir Lyra[4, 2]
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Stellar mass black hole seeds can rapidly grow into intermediate mass black holes (IMBH) in accretion disks around supermassive black holes. Initial seed growth is dominated by collisions with stars and later seed growth is dominated by gas accretion. IMBH grow much faster in this model than in globular cluster. There are strong theoretical and observational analogies with the growth of Jupiters in disks around stars. I discuss the growth and observational signatures of IMBH in AGN disks.

223.03 – Hiding a supermassive black hole behind dusty, infrared-driven flows in Type-2 AGN: results from radiation-hydrodynamics simulations

Anton Dorodnitsyn[1]
1. NASA GSFC/UMD, Greenbelt, MD, United States.
Contributing teams: T. Kallman, G.S. Bisnovatyi-Kogan

Observational properties of active galactic nuclei are essentially influenced by their winds. I will present the results from the multidimensional, flux-limited diffusion radiation hydrodynamics simulations of the dusty obscuring flows in AGN. Simulations show that the illumination of a parsec-scale, geometrically thin, dusty accretion disk by X-rays, and UV, forces the disk to become geometrically thick due to pressure of the reprocessed IR radiation on dust. If AGN luminosity exceeds 0.1Ledd the outer part of the disk develops a rigorous IR-driven accretion disk wind. This dense wind provides most of the obscuration making an AGN to appear as Type-2. The inner hot and photoionized part of the same large scale wind has properties similar to those of a warm absorber flow. At luminosities ≤0.1Ledd episodes of the outflow are followed by periods when the wind switches to slow accretion.

223.04 – A New Analytical Model for X-Ray Time Lags from Accreting Black Holes

John J. Kroon[1], Peter A. Becker[1]
1. George Mason University, Fairfax, VA, United States.

Accreting black holes show a wide variety of rapid time variability including the manifestation of X-ray time lags, in which the hard or soft component of the signal arrives later than the other component. Despite a large body of observational evidence for time lags, no coherent theoretical model explaining the physical origin of these lags has been presented. In this presentation, we reexamine the problem by developing a new analytical model for the production of X-ray time lags based on the diffusion and Comptonization of seed photons in a spherical homogeneous corona. Starting with the fundamental transport equation, we obtain an exact analytical solution for the Fourier transform of the Green's function resulting from an instantaneous flash of monochromatic radiation in a thin radial shell. The Green's function is convolved with a bremsstrahlung source spectrum to compute the time lags associated with a localized broadband flash resulting from an

instability in the disk. The diffusion and Comptonization of the bremsstrahlung seed photons as they propagate towards the edge of the cloud naturally produces a time lag that diminishes with increasing Fourier frequency, in agreement with the observations for a variety of accreting black hole sources. Hence the new model can be used to interpret a large body of existing and future timing observations of X-ray transients from black hole sources.

223.05 – Constraining MHD Disk-Winds with X-ray Absorbers

Keigo Fukumura[4], Francesco Tombesi[3], Chris R. Shrader[5], Demosthenes Kazanas[5], John Contopoulos[2], Ehud Behar[1]
1. Technion, Haifa, Israel. 2. Academy of Athens, College ParkAthens, Greece. 3. UMD, College Park, MD, United States. 4. James Madison University, Harrisonburg, VA, United States. 5. NASA/GSFC, Greenbelt, MD, United States.

From the state-of-the-art spectroscopic observations of active galactic nuclei (AGNs) the robust features of absorption lines (e.g. most notably by H/He-like ions), called warm absorbers (WAs), have been often detected in soft X-rays (< 2 keV). While the identified WAs are often mildly blueshifted to yield line-of-sight velocities up to ~100-3,000 km/sec in typical X-ray-bright Seyfert 1 AGNs, a fraction of Seyfert galaxies such as PG 1211+143 exhibits even faster absorbers (v/c~0.1-0.2) called ultra-fast outflows (UFOs) whose physical condition is much more extreme compared with the WAs. Motivated by these recent X-ray data we show that the magnetically- driven accretion-disk wind model is a plausible scenario to explain the characteristic property of these X-ray absorbers. As a preliminary case study we demonstrate that the wind model parameters (e.g. viewing angle and wind density) can be constrained by data from PG 1211+143 at a statistically significant level with chi-squared spectral analysis. Our wind models can thus be implemented into the standard analysis package, XSPEC, as a table spectrum model for general analysis of X-ray absorbers.

223.06 – Polarization Features of AGN Dusty Plasmas

Ericson Lopez[1, 2], Susana E. Deustua[2]
1. Quito Astronomical Observatory of National Polytechnic School, Quito, Ecuador. 2. Space Telescope Sciences Institute, Baltimore, MD, United States.

Faraday rotation provides a direct diagnostic for the presence of magnetized material through observations of the change in the state of polarization with the frequency, as the radiation passes through the magneto-ionic media along the line of sight. The normal rotation of the plane of polarization as it propagates through a region with a magnetic field, should also be affected by the ions and dust in the plasma. In many situations electrons are the dominant factor affecting polarization. Here, we discuss astrophysical conditions where the contribution of dust and ions are significant, comparable to that of electrons.

223.07 – Advances in Reverberation Mapping of Quasars: Techniques, Experiments, and Implications

Kelly Denney[1]
1. Ohio State University, Columbus, OH, United States.

Reverberation mapping is the only method capable of directly measuring the mass of supermassive black holes in galaxies outside the local universe. In addition, it has the potential to act as a cosmological distance probe to sources spanning 0 < z <~ 4. This method is applicable to broad line active galaxies, or quasars, by taking advantage of the light travel time delay between variability signals observed from the central black hole accretion disk continuum emission and from the photoionized line-emitting gas in the vicinity of the central source. This shifts the observational requirements from spatial dependence to temporal dependence in order to resolve the central structure. So far, reverberation mapping experiments have primarily been carried out locally (z < 0.3), but I will discuss how several new experiments are targeting more distant sources and/or using more time efficient methods to apply this technique to quasars with a broader range of observed spectral characteristics and across cosmological scales. I will also discuss how the resulting measurements have the potential to impact our understanding of cosmology and dark energy.

223.08 – Space-Based Aperture-Masking Interferometry of Active Galactic Nuclei

K.E. S. Ford[1, 2], Barry McKernan[1, 2], Anand Sivaramakrishnan[3, 2], Andre Martel[3], David Lafreniere[5], Sebastien Parmentier[4], Anton M. Koekemoer[3]
1. Borough of Manhattan Community College - CUNY, New York, NY, United States. 2. American Museum of Natural History, New York, NY, United States. 3. Space Telescope Science Institute, Baltimore, MD, United States. 4. Stony Brook University - SUNY, Stony Brook, NY, United States. 5. University of Montreal, Montreal, QC, Canada.

JWST will include a seven-hole non-redundant pupil mask, to be used in Near Infrared Imager and Slitless Spectrograph's

(NIRISS) Aperture-Masking Interferometry mode (AMI) operating at 2.77, 3.8, 4.3, and 4.8 μm. We look at the utility of NIRISS-AMI for the study of AGNs. We show how moderate constrast, high angular resolution, small inner working angle images can advance our understanding of AGN feedback, fuelling, structure and binarity. Using realistic noisy simulations of JWST NIRISS-AMI we demonstrate how extended structures and asymmetries around AGNs may be imaged at moderate contrast, including bar- and ring-like structures. We also compare JWST (and future mission) NRM's ability to perform true imaging with current and future ground-based NRM, which relies heavily on model-fitting.

224 – Astronomy Education Policy, EPO Programs, and Undergraduate Education

Oral Session – Maryland 2 – 07 Jan 2014 02:00 pm to 03:30 pm

224.01 – Science Education & Advocacy: Tools to Support Better Education Policies

Christine O'Donnell[1, 2], Beth Cunningham[2], Jack G. Hehn[2]
1. University of Virginia, Charlottesville, VA, United States. 2. American Association of Physics Teachers, College Park, MD, United States.

Education is strongly affected by federal and local policies, such as testing requirements and program funding, and many scientists and science teachers are increasingly interested in becoming more engaged with the policy process. To address this need, I worked with the American Association of Physics Teachers (AAPT) --- a professional membership society of scientists and science teachers that is dedicated to enhancing the understanding and appreciation of physics through teaching --- to create advocacy tools for its members to use, including one-page leave-behinds, guides for meeting with policymakers, and strategies for framing issues. In addition, I developed a general tutorial to aid AAPT members in developing effective advocacy strategies to support better education policies. This work was done through the Society for Physics Students (SPS) Internship program, which provides a range of opportunities for undergraduates, including research, education and public outreach, and public policy. In this presentation, I summarize these new advocacy tools and their application to astronomy education issues.

224.02 – Impact of NASA's Astrophysics Education and Public Outreach Programs

Denise A. Smith[1], Hashima Hasan[2]
1. STScI, Baltimore, MD, United States. 2. NASA Headquarters, Washington, DC, United States.

NASA has through the years developed a diverse portfolio of Education and Public Outreach (E/PO) programs that have taken the science of NASA's Astrophysics missions into classrooms, museums, planetaria and other public venues. From lesson plans, teacher workshops, public exhibitions, to social media and citizen science, these programs have reached vast audiences internationally. NASA's Science and Education Outreach Forums have developed valuable resources, such as NASA Wavelength, which is a user friendly website of a catalog of NASA's E/PO programs. A sample of programs and their metrics will be presented to demonstrate the impact of the NASA Science Mission Directorate E/PO program in providing a direct return on the public's investment in NASA science.

224.03 – The ASP at 125: Advancing Science Literacy in an Age of Acceleration

Jim Manning[1]
1. Astronomical Society of the Pacific, San Francisco, CA, United States.

On February 7, 2014, the Astronomical Society of the Pacific will celebrate its 125th birthday and a century and a quarter of advancing astronomy and astronomy/science education during a period of revolutionary change in our understanding of the universe. In keeping with both the retrospective and forward-looking nature of such milestones, the presenter will: 1) share highlights of the Society's work in supporting the communication of astronomy research through its professional publications, and creating innovative astronomy education and public outreach projects and networks to advance student, teacher and public understanding of astronomy and science; 2) report on current NASA- and NSF-funded efforts and on plans going forward; 3) and solicit input from the assembled community on how the ASP can best serve its various constituencies and the cause of science education, communication and literacy at a time when both the universe and life on Earth are accelerating at unprecedented rates. Birthdays are for celebrating; come celebrate with us as we rededicate ourselves to a mission of advancing science literacy through astronomy.

224.04 – Findings from a NASA SMD Survey of Two-Year College Faculty

Gregory R. Schultz[1], Russanne Low[2], Emily CoBabe-Ammann[3], Nicholas Gross[4], Sanlyn Buxner[5]
1. Astronomical Society of the Pacific, San Francisco, CA, United States. 2. Institute for Global Environmental Strategies, Arlington, VA, United States. 3. University Corporation for Atmospheric Research, Boulder, CO, United States. 4. Boston University, Boston, MA, United States. 5. Planetary Science Institute, Tucson, AZ, United States.

The Higher Education Working Group (HEWG) of the NASA Science Mission Directorate (SMD) Science Education and Public Outreach Forums conducted a survey of Earth and space science faculty in two-year/community (2YR) colleges. The purpose of the study was to inform the work of the NASA SMD Forums, tasked with making recommendations to best achieve NASA's strategic objectives with respect to STEM education support and STEM workforce development. The specific aim was to

better understand the challenges and opportunities with regard to NASA SMD E/PO engagement with 2YR colleges – who teaches there, what students need, and most importantly, what the barriers are to bringing NASA-related STEM into the classroom. The HEWG developed and, starting in Aug 2012, disseminated a survey to community college faculty to better understand instructor needs, their students and institutional context, their professional development (PD), and how they bring new science into their classrooms. The survey was open for a few months, and we had responses nationwide from 183 faculty who teach in community colleges. We present results of the survey here, including demographics, teaching responsibilities, and what kinds of professional support 2YR faculty say they most need from the broader EPO community. We also include 2YR faculty feedback and results from face-to-face group sessions held in summer 2013.

224.05 – Introductory Astronomy Student-Centered Active Learning at The George Washington University

Bethany Cobb[1]
1. George Washington University, Washington, DC, United States.

The Physics Department at the George Washington University has been successfully using student-centered active learning (SCALE-UP) in physics classes since 2008. In Fall 2011, we began implementing introductory (non-majors) astronomy classes taught in the student-centered active learning mode. Class time is devoted to engaging in hands-on activities and laboratories, and tackling thought-provoking questions and problems. Students work together in small groups to gain a deeper understanding of the material. Multiple instructors circulate to answer questions and engage students in additional contemplation of the material. Research has shown that students who are engaged in this manner have an increased conceptual understanding and are better able to solve problems. This talk will describe our methods, our successes and the associated challenges of integrating active learning into courses entitled "Stars, Planets and Life" and "Introduction to the Cosmos."

224.06 – SkyServer Voyages: Next-Generation Educational Activities using the Sloan Digital Sky Survey

Kate Meredith[1], Jordan Raddick[1], Britt Lundgren[2]
1. Johns Hopkins University, Baltimore , MD, United States. 2. University of Wisconsin , Madison, WI, United States.

The Sloan Digital Sky Survey (SDSS) "SkyServer" has long included online educational materials designed to enable students and the public to discover the fundamentals of modern astronomy using real observations from the SDSS database. Efforts are now being made to update and expand these activities to reflect new data from additional generations of the survey (e.g., SDSS-III), advances in web capabilities and changing trends in science education. The new site, "SkyServer Voyages", aims to provide access to quality astronomy, astrophysics and engineering materials to educators with a particular focus on those seeking to implement the new Next Generation Science Standards (NGSS) in the US. We provide an overview of the design and development of Skyserver Voyages and discuss ways to apply this resource at the K-12 and university levels.

224.07 – THE SPACE PUBLIC OUTREACH TEAM (SPOT)

Kathryn Williamson[1]
1. Montana State University, Bozeman, MT, United States.
Contributing teams: National Radio Astronomy Observatory, Montana Space Grant Consortium, West Virginia Space Grant Consortium, NASA Independent Verification and Validation Center

The Space Public Outreach Team (SPOT) has shown over 17 years of success in bringing astronomy and space science-themed presentations to approximately 10,000 students per year in Montana, and the program is now being piloted in West Virginia through a joint partnership between the National Radio Astronomy Observatory (NRAO), the West Virginia Space Grant Consortium, and NASA Independent Verification and Validation Center. SPOT recruits and trains undergraduate presenters from all over the state to learn interactive slide shows that highlight the state's on-going and world-class space science research. Presenters then travel to K-12 schools to deliver these presentations and provide teachers additional supplemental information for when the SPOT team leaves. As a large-scale, low-cost, and sustainable program being implemented in both Montana and West Virginia, SPOT has the potential to become a nation-wide effort that institutions in other states can model to increase their education and public outreach presence.

224.08 – Inspiring a future generation of Astronomer and Astrophysicists during the 48th and 49th annual Astro-Science Workshop

Michael Martynowycz[1, 2], Gayle Ratliff[1, 2], Geza Gyuk[2], Mark Hammergren[2]
1. Illinois Institute of Technology, Chicago, IL, United States. 2. Adler Planetarium & Astronomy Museum, Chicago, IL, United States.

Aging of the technological workforce and declining STEM interest among teens gives impetus to a more exciting, hands-on approach to science education. As one of the longest running astronomy & astrophysics programs for high school students in the country, the Adler Planetarium's Astro-Science Workshop (ASW) has continually evolved to best serve the out-of-school time needs of science-interested teens in the region. More than a decade ago, ASW underwent a major shift in underlying philosophy from a traditional lecture-oriented program to one focused on hands-on, student led inquiry in which students design, build, and conduct their own experiments. This strategy capitalizes on the natural inclinations of curious youth, and has found a strong synergy with the emerging "maker" movement. Over the past two years, a very successful effort has been made to retain students following ASW as volunteers in the Adler's Far Horizons high-altitude ballooning group. The necessity to continually inspire and spark interests in science futures in our youth has been ongoing; this intense program serves this niche while giving students experiences they will keep with them for their entire lives. Here, we share our successes, failures, and future perspectives on astronomy education and the mission of widening the future pipeline of young scientists in the nation.

224.09 – Dark Skies Africa: an NOAO and IAU OAD Program on Light Pollution

Constance E. Walker[1], Daniel Tellez[1], Stephen M. Pompea[1]
1. NOAO, Tucson, AZ, United States.

The IAU's Office of Astronomy for Development (OAD) awarded the National Optical Astronomy Observatory (NOAO) with a grant to deliver a "Dark Skies Outreach to Sub-Saharan Africa" program to institutions in 12 African countries during 2013. The program helped students identify wasteful and inefficient lighting and provided ways to reduce consumption and to keep energy costs in check. The goal was to inspire students to be responsible stewards in helping their community safeguard one of Africa's natural resources - a dark night sky. Thirteen kits made by the NOAO Education and Public Outreach group were sent to coordinators at university, science center and planetarium-type institutions in 12 African countries and to the IAU OAD. The program's kit included complete instructional guides and supplies for six activities and a project on energy conservation and responsible lighting. The six activities were taught to the coordinators in a series of six Google+ Hangout sessions scheduled from June to mid-November. The coordinators at the institutions in the twelve countries in turn trained local teachers in junior and senior high schools. The Google+ Hangout sessions also included instruction on carrying out evaluations. From the end of November until mid-December students from the different African countries shared final class projects (such as posters or powerpoints) on the program's website. The entire program was designed to help coordinators and educators work with students, parents and the community to identify dark sky resource, lighting and energy issues and to assess their status, efficiency and effectiveness. Participants will take away from the presentation new techniques on using Google+ Hangout sessions to instruct and sustain a community of coordinators and educators through distance learning as well as immersing them (and their students) in Project Based Learning after a scaffolded sequence of activities.

225 – Astrophysics Code Sharing II: The Sequel

Special Session – National Harbor 5 – 07 Jan 2014 02:00 pm to 03:30 pm

Research in astronomy is increasingly dependent on software methods, yet these methods are often not revealed, inhibiting re-use and undermining a basic tenet of scientific research: reproducibility. Building on the findings of the January 2013 AAS splinter meeting "Astrophysics Code Sharing?", which brought to light issues with sharing computational research methods, this session, organized by the AAS's Working Group on Software (WGAS) and the Astrophysics Source Code Library (ASCL), explores how we as a community can better support making codes used in research available for others to examine. A panel of speakers will discuss the state of code sharing, funding agencies' policies, and, illustrated by case studies, the benefits and pitfalls of releasing code. The case studies are presented by the authors of codes with varying times in the community, from new efforts to well-entrenched software. They will share the issues that arose when they released their codes, how they dealt with or mitigated the issues, and what benefits arose from releasing their software. They will also discuss what they learned through the process and their best practices. The floor will then be open for discussion on ways to encourage code sharing to improve the transparency and efficiency of research and mitigate the negative aspects of releasing code.

225.01 – Occupy Hard Drives: Making your work more valuable by giving it away

Benjamin J. Weiner[1]

1. University of Arizona, Tucson, AZ, United States.

Astronomy is more than ever reliant on scientist-built software, but our systems of supporting research and giving credit for research work have failed to evolve with this reality. Both the perception of short term advantage, and an artificial distinction between "tools" and "science," lead to software and data remaining proprietary or unpublished. The lack of incentives to build and maintain software leads to both a decay of the software infrastructure, and a potential for growing class inequality, a pundit-technician divide. Top-down efforts to direct the field such as the recent US decadal survey have not adequately addressed this future. I argue that writing, freely releasing, and publishing your software is currently not adequately funded, rewarded, or credited, and that you should do it anyway. Writing your software as if you plan to release it is better for you and for the code. Releasing software can get credit from the rest of the community beyond your circle of collaborators or letter-writers, and it can benefit you and everyone else by making astronomy a better place to work. Building a culture of cooperation will be a more effective approach to reforming the system of credit than waiting for leadership from above or outside, but requires that each of us consciously encourage process, values, and behavior that support such a change.

225.02 – Maintaining A User Community For The Montage Image Mosaic Toolkit.

G. B. Berriman[1]

1. Caltech, Pasadena, CA, United States.

The development of the Montage image mosaic toolkit was funded by NASA between 2002 and 2005. Even though the code has been unfunded for eight years, the user community of astronomers and computer scientists has continued to grow, primarily because the code is portable across Unix platforms, highly scalable, and easy to incorporate into user environments and pipelines. The code is publicly available through a clickwrap license at Caltech, but the license does not permit the user to modify and redistribute the software. This presentation outlines successful strategies for maintaining and upgrading Montage in the face of the licensing restrictions and absence of continuing funding, and outlines cases where the restrictions have limited further development.

225.03 – Cloudy – simulating the non-equilibrium microphysics of gas and dust, and its observed spectrum

Gary J. Ferland[1]

1. Univ. of Kentucky, Lexington, KY, United States.

Cloudy is an open-source plasma/spectral simulation code, last described in the open-access journal Revista Mexicana (Ferland et al. 2013, 2013RMxAA..49..137F). The project goal is a complete simulation of the microphysics of gas and dust over the full range of density, temperature, and ionization that we encounter in astrophysics, together with a prediction of the observed spectrum. Cloudy is one of the more widely used theory codes in astrophysics with roughly 200 papers citing its documentation each year. It is developed by graduate students, postdocs, and an international network of collaborators. Cloudy is freely available on the web at trac.nublado.org, the user community can post questions on http://groups.yahoo.com/neo/groups/cloudy_simulations/info, and summer schools are organized to learn more about Cloudy and its use (http://cloud9.pa.uky.edu/~gary/cloudy/CloudySummerSchool/). The code's widespread use is possible because of extensive automatic testing. It is exercised over its full range of applicability whenever the source is changed. Changes in predicted quantities are automatically detected along with any newly introduced problems. The code is designed to be autonomous and self-aware. It generates a report at the end of a calculation that summarizes any problems encountered along with suggestions of potentially incorrect boundary conditions. This self-monitoring is a core feature since the code is now often used to generate large MPI grids of simulations, making it impossible for a user to verify each calculation by hand. I will describe some challenges in developing a large physics code, with its many interconnected physical processes, many at the frontier of research in atomic or molecular physics, all in an open environment.

225.04 – NSF Policies on Software and Data Sharing and their Implementation

Daniel Katz[1]

1. National Science Foundation, Arlington, VA, United States.

Since January 2011, the National Science Foundation has required a Data Management plan to be submitted with all proposals. This plan should include a description of how the proposers will share the products of the research (http://www.nsf.gov/bfa/dias/policy/dmp.jsp). What constitutes such data will be determined by the community of interest through the process of peer review and program management. This may include, but is not limited to: data, publications, samples, physical collections, software and models. In particular, "investigators and grantees are encouraged to share software and inventions created under an award or otherwise make them or their products widely available and usable."

225.05 – The Astropy Project's Self-Herding Cats Development Model

Erik J. Tollerud[1]

1. Yale University, New Haven, CT, United States.

The Astropy Project is a community effort to develop open source tools for doing astronomy and astrophysics with the Python programming language. The project has grown rapidly in the past few years, in large part due to its completely open source/shared development model. This is especially remarkable given that a large fraction of the contributors are actively working astronomers in disparate fields. I will describe some of the strategies that have helped the project attract and maintain active contributors and users (as well as some that have not). I will also emphasize the importance for Astropy of leveraging the infrastructure that already exists for open source software development, and how this may translate to other astronomy codes.

225.06 – Costs and benefits of developing out in the open

David W. Hogg[1]

1. New York Univ., New York, NY, United States.

My group has 8 years of experience developing source code in entirely in the open, in publicly available version-control repositories. Even papers being drafted for the scientific literature and proposals for research funding are developed in full public view. The costs of this sharing include some risk from competitors and some inappropriate requests for help and information. The benefits include higher profile for our work, ease of communicating methods and results to outsiders, voluntary contributions of ideas and code from unaffiliated scientists, and good-will from the community. For my work, the benefits have enormously outweighed the costs; it might be that extreme openness is the right model when "ideas are cheap, implementations are expensive".

226 – Cosmology & CMB IV

Oral Session – Maryland Ballroom C – 07 Jan 2014 02:00 pm to 03:30 pm

226.01 – Innovative Cosmology with Cosmic Voids

Paul M. Sutter[1,2], Benjamin Wandelt[1,3], David H. Weinberg[2], Michael S. Warren[4], Nico Hamaus[1]
1. Paris Institute of Astrophysics, Paris, Ile-de-France, France. 2. Ohio State University, Columbus, OH, United States. 3. University of Illinois at Urbana-Champaign, Urbana, IL, United States. 4. Los Alamos National Laboratory, Los Alamos, NM, United States.

Voids are the large, underdense regions in the cosmic web. While they are obviously useful cosmological probes, due to their intimate connection to the growth of structure, they are also interesting places to study astrophysics such as neutrino mass and primordial magnetic fields. I will present the latest work to identify voids in galaxy redshift surveys, how they connect to underdensities in dark matter, and the first results in exploiting their properties (sizes, shapes, interior contents) for scientific gain.

226.02 – A Path to the Past: Observing High Redshifts Using Cross-Correlations

Elizabeth R. Fernandez[1]
1. Kapteyn Astronomical Institute, Groningen, Netherlands.

Understanding the Epoch of Reionization is one of the goals of modern cosmology. During this period of time, star formation started, the universe became metal enriched, and structures grew. However, observing this period of time is very challenging. I will discuss how we can use cross-correlations between various wavelengths, especially in the infrared and radio, to extract more information on this stage of the universe. I will discuss the prospects of detecting the Epoch of Reionization using the 21cm line with LOFAR, as well as the significance of any high redshift component of the cosmic infrared background.

226.03 – Fermat Potentials of Embedded Lensing, the Integrated Sachs-Wolfe Effect, and Weak-Lensing of CMB by Cosmic Voids

Bin Chen[1], Ronald Kantowski[1], Xinyu Dai[1]
1. University of Oklahoma, Norman, OK, United States.

We have developed an accurate gravitational lens theory for an inhomogeneity embedded in an otherwise homogeneous universe, which to the lowest order is applicable to any mass distribution. We derive the Fermat potential for a spherically symmetric lens embedded in a FLRW cosmology and use it to investigate the late-time integrated Sachs-Wolfe effect (ISW) caused by individual large scale inhomogeneities, in particular, cosmic voids. We present a simple analytical expression for the CMB temperature fluctuation across such a lens as the derivative of the lens Fermat potential. Our formalism is applicable to both linear and nonlinear density evolution scenarios, to arbitrarily large density contrasts, and to all open and closed background cosmologies. Our results are particularly useful for modeling ISW effects extracted through stacking large numbers of cosmic voids and clusters (that is, the aperture photometry method). For structures co-expanding with the background cosmology, i.e., for time-independent density contrasts, we find that the gravitational lensing time delay alone can produce fluctuations of the order of seen in recent observations by WMAP and Planck. We revisit the possibility of explaining the non-Gaussian cold spot on the south hemisphere via the Rees-Sciama effect of a large cosmic void using constraints obtained from the most recent void catalogs and our new void-lensing formalism, and compare it with other explanations such as a collapsing cosmic texture. We also study the remapping of primordial CMB anisotropies, the weak-lensing shear, and magnification caused by void lensing.

226.04 – Finding the 99% Today: The Cosmological Role of Dwarf Galaxies

Aparna Venkatesan[1]
1. Univ. of San Francisco, San Francisco, CA, United States.

Dwarf galaxies are thought to be extremely numerous at early times, and the possible building blocks of many of the galaxies in the modern-day universe. In this all-too-short talk, I will present recent calculations of the escape fraction of ionizing radiation from early low-mass galaxies and their potential impact on cosmic reionization. I will also discuss the tantalizing similarities in element abundance patterns between ultra-faint dwarf spheroidal galaxies in the local universe and the extremely metal-poor stars in the Galactic halo. Gas-rich low-mass systems such as the metal-poor nearby dwarf irregular galaxy Leo P, recently discovered in the Arecibo ALFALFA survey, may have survived cosmic reionization and provide additional clues on the cosmological role of dwarf galaxies. This work was supported by Research Corporation through the Single Investigator Cottrell College Science Award, the University of San Francisco Faculty Development Fund, and NSF grant AST-121100.

226.05 – Cosmological Constraints from applying SHAM to rescaled cosmological simulations

Vimal Simha[1]

1. Durham University, Durham, United Kingdom.

We place constraints on the matter density of the Universe and the amplitude of clustering using measurements of the galaxy two-point correlation function from the Sloan Digital Sky Survey (SDSS). We generate model predictions for different cosmologies by populating rescaled N-body simulations with galaxies using the subhalo abundance matching (SHAM) technique. We find $?M = 0.29 \pm 0.03$ and $?8 = 0.86 \pm 0.04$ at 68% confidence from fitting the observed two-point galaxy correlation function of galaxies brighter than $Mr = -18$ in a volume limited sample of galaxies obtained by the SDSS. We discuss and quantify potential sources of systematic error, and conclude that while there is scope for improving its robustness, the technique presented in this paper provides a powerful low redshift constraint on the cosmological parameters that is complementary to other commonly used methods.

226.06 – Large-Scale Structure Formation with Dark Energy and Massive Neutrinos

Amol Upadhye[1, 2], Rahul Biswas[1], Adrian C. Pope[1], Katrin Heitmann[1, 2], Salman Habib[1, 2], Hal Finkel[1], Nicholas Frontiere[1, 2]

1. Argonne National Laboratory, Argonne, IL, United States. 2. University of Chicago, Chicago, IL, United States.

Over the next decade, cosmological measurements of the large-scale structure of the Universe will determine the combined mass of the neutrinos and will significantly constrain evolution of the dark energy density. I will discuss the extension of the Time-RG higher-order cosmological perturbation theory to models with dynamical dark energy and massive neutrinos, and I will establish its validity through comparison to N-body dark matter simulations. For models without massive neutrinos I will also quantify the accuracy of Standard, Renormalized, and Lagrangian perturbation theories. An approximation that neglects neutrino inhomogeneities as sources for matter clustering predicts the Baryon Acoustic Oscillation (BAO) peak position to 0.25% accuracy for redshifts $1 < z < 3$, justifying the use of Lagrangian perturbation theory for BAO reconstruction in upcoming surveys.

226.07 – Using gaps in N-body tidal streams to probe missing satellites

Wayne Ngan[1], Raymond G. Carlberg[1]

1. University of Toronto, Toronto, ON, Canada.

We use N-body simulations to model the tidal disruption of a star cluster in a Milky Way sized dark matter halo, which is modelled by a spherical NFW potential with subhalos as predicted by the LCDM cosmological model. The resulting star stream has a narrow range of angular momentum and a radial velocity dispersion of about 1 km/sec with prominent epicyclic over-densities near the progenitor. We use a matched filter approach to look for "gaps" in tidal streams at five length scales from 0.3 kpc to 0.5 kpc, which appear with characteristic dips in the linear density along the streams. We quantify the abundance gaps at those scales with and without the contribution of subhalos. Our results indicate that measurements of density variations along a stream, and eventually the 2D structure of streams, is a valuable probe of the substructure of the Galactic halo.

226.08 – Objects Appear Smaller as They Recede: How Proper Motions Can Directly Reveal the Cosmic Expansion, Provide Geometric Distances, and Measure the Hubble Constant

Jeremiah K. Darling[1]

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Objects and structures gravitationally decoupled from the Hubble expansion will appear to shrink in angular size as the universe expands. Observations of extragalactic proper motions can thus directly reveal the cosmic expansion. Relatively static structures such as galaxies or galaxy clusters can potentially be used to measure the Hubble constant, and test masses in large scale structures can measure the overdensity. Since recession velocities and angular separations can be precisely measured, apparent proper motions can also provide geometric distance measurements to static structures. The apparent fractional angular compression of static objects is 15 μas yr^{-1} in the local universe; this motion is modulated by the overdensity in dynamic expansion-decoupled structures. We use the Titov et al. (2011) quasar proper motion catalog to examine the pairwise proper motion of a sparse network of test masses. Small-separation pairs (less than 200 Mpc comoving) are too few to measure the expected effect, yielding an inconclusive 8.3 $\pm$ 14.9 μas yr^{-1}. Large-separation pairs (200–1500 Mpc) show no net convergence or divergence for $z < 1$, 2.7 $\pm$ 3.7 μas yr^{-1}, consistent with pure Hubble expansion and

significantly inconsistent with static structures, as expected. For all pairs a ``null test'' gives 0.36 ± 0.62 μas yr^{-1}, consistent with Hubble expansion, and excludes a static locus at ?5–10 ? significance for z ? 0.5–2.0. The observed large-separation pairs provide a reference frame for small-separation pairs that will significantly deviate from the Hubble flow. The current limitation is the number of small-separation objects with precise astrometry, but Gaia will address this and will likely detect the cosmic recession.

226.09 – A Novel Suite of Hydrodynamical Simulations of the Lyman-Alpha Forest with Massive Neutrinos

Graziano Rossi[1], Nathalie Palanque-Delabrouille[1], Christophe Yeche[1], Matteo Viel[2, 3], James Rich[1], Jean-Marc LeGoff[1], Arnaud Borde[1]

1. CEA, Centre de Saclay, Irfu/SPP, Gif-sur-Yvette, France. 2. INAF - Osservatorio Astronomico di Trieste, Trieste, Italy. 3. INFN/National Institute for Nuclear Physics, Trieste, Italy.

We present a suite of state-of-the-art hydrodynamical simulations with cold dark matter, baryons and massive neutrinos, specifically targeted for modeling the low-density regions of the intergalactic medium (IGM) as probed by the Lyman-Alpha forest at high-redshift. The simulations span volumes ranging from (25 Mpc/h)^3 to (100 Mpc/h)^3, and are made using either 3×192^3 ~ 21 millions or 3×768^3 ~ 1.4 billion particles – with cosmological parameters compatible with the latest Planck (2013) results. While our realizations have been specifically designed to meet the requirements of the Baryon Acoustic Spectroscopic Survey (BOSS), they can also be utilized for upcoming or future experiments – such as eBOSS and MS-DESI - since the overall resolution can be further enhanced so that one could reach the equivalent of 3×3072^3 ~ 87 billion particles in a (100 Mpc/h)^3 box size. We improve on pre-exisiting modeling in several ways, in particular with new prescriptions for IGM radiative cooling and heating processes, a more updated re-ionization history, and initial conditions based on 2LPT rather than the Zeldovich approximation. Combining data from BOSS and the Planck satellite, and with a grid of corresponding LCDM simulations, our mocks will allow us to constrain cosmological parameters and neutrino masses directly from the Lyman-Alpha forest with unprecedented sensitivity. The simulations can also be useful for a broader variety of cosmological studies, and willl be made available to the scientific community upon request.

227 – Evolution of Emission Line Galaxies
Oral Session – Potomac Ballroom D – 07 Jan 2014 02:00 pm to 03:30 pm

227.01 – ``Direct'' Gas-Phase Metallicities, Stellar Properties, and Local Environments of Emission-Line Galaxies at Redshifts below 0.9"

Chun Ly[1,2], Matthew A. Malkan[3], Tohru Nagao[4], Nobunari Kashikawa[6], Kazuhiro Shimasaku[5], Masao Hayashi[6]

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Using deep narrow-band (NB) imaging and optical spectroscopy from the Keck telescope and MMT, we identify a sample of 20 emission-line galaxies (ELGs) at z=0.07--0.90 where the weak auroral emission line, [OIII]4363, is detected at ?3?. These detections allow us to determine the gas-phase metal abundances using the ``direct'' method. After correcting the emission-line fluxes for dust attenuation using Balmer decrements, we find that 10 of these low-mass galaxies are extremely metal-poor with $12+\log(O/H) \leq 7.65$ dex or one-tenth solar. Considering measurement uncertainties, we argue that 8 and 4 of them are extremely metal-poor at the 85% and 95% confidence levels, respectively. This result supports previous claims that NB imaging is an effective technique to identify extremely-metal poor galaxies at z≤1. Our three most metal-deficient galaxies have $12+\log(O/H) = 7.05$--7.12, similar to some of the lowest metallicity galaxies identified in the local universe. We also find that our galaxies are all undergoing significant star formation with average specific star formation rate (SFR) of $(100 \text{ Myr})^{-1}$, and that they have high central SFR surface densities (average of 0.5 M™/yr/kpc^2). In addition, more than two-thirds of our galaxies have between one and four nearby companions within a projected radius of 100 kpc, which we find is an excess among star-forming galaxies at z=0.4--0.8. We also examine how the gas-phase metallicities compare with the stellar mass and the SFR of the galaxies, and find that while roughly half of our galaxies lie along the M*--Z--(SFR) relation, the other half have metallicities that are 0.1--1 dex lower than predicted. Our analysis suggests that this discrepancy is real at the 95% confidence. This indicates that the *local* M*--Z--(SFR) relation may not hold for all low-mass galaxies ($\leq 10^9$ M™) at z=0.4--0.8. The high ionization parameter and high electron density seen in our galaxies suggest that they are lower redshift analogs to typical z?1 galaxies.

227.02 – The NewHα Survey: Investigating the Fundamental Metallicity Relation at z?0.8

Mithi De Los Reyes[1], Janice C. Lee[2], Chun Ly[2], Samir Salim[3], Ivelina G. Momcheva[4,5], Jesse Feddersen[4,3], Daniel A. Dale[6], Masami Ouchi[7], Yoshiaki Ono[7], Rose Finn[8]

1. North Carolina State University, Raleigh, NC, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. Indiana University, Bloomington, IN, United States. 4. Yale University, New Haven, CT, United States. 5. Carnegie Observatories, Pasadena, CA, United States. 6. University of Wyoming, Laramie, WY, United States. 7. University of Tokyo, Kashiwa City, Chiba, Japan. 8. Siena College, Loudonville, NY, United States.

The NewHα narrowband imaging survey, combined with deep follow-up spectroscopy with Magellan-IMACS, provides both Hα and rest-frame optical emission lines for sources at z?0.8—an uncommon combination for previous surveys at such redshifts. We use observations for ?100 galaxies to estimate global galactic properties, including stellar mass (M∗), star formation rate (SFR), and gas-phase metallicity (12+log[O/H]). Star formation rates are measured using Hα fluxes (and compared to estimates from SED fitting that include rest-frame far UV fluxes), while gas-phase metallicities are estimated from optical emission line fluxes using a range of standard calibrations. We compare our mass-metallicity relation and mass-SFR relation (known as the "star formation main sequence") with literature results. We also combine the three parameters and examine whether the "Fundamental Metallicity Relation" exists and is consistent with previous results based on the Sloan Digital Sky Survey. Implications for galaxy evolution are discussed.

227.03D – Physical Properties of Emission-Line Galaxies at z~2 from Near-Infrared Spectroscopy with Magellan FIRE

Daniel C. Masters[1,2], Patrick J. McCarthy[2], Matthew A. Malkan[3], Brian D. Siana[1], Claudia Scarlata[5], Nimish P. Hathi[6], Hakim Atek[7], Alaina L. Henry[4]

1. Physics & Astronomy, University of California, Riverside, Pasadena, CA, United States. 2. Carnegie Observatories, Pasadena, CA, United States. 3. University of California, Los Angeles, Los Angeles, CA, United States. 4. Goddard Space Flight Center, Greenbelt, MD, United States. 5. University of Minnesota, Minneapolis, MN, United States. 6. Laboratoire d'Astrophysique de

Marseilles, Marseilles, France. 7. Laboratoire d'Astrophysique Ecole Polytechnique, Sauverny, Switzerland.
Contributing teams: WISP team

We present results from near-infrared spectroscopy with Magellan FIRE of 26 strong emission-line galaxies at z~2.2 and z~1.5. The sample was selected from the WFC3 Infrared Spectroscopic Parallels (WISP) survey, which uses the near-infrared grism capability of the Hubble Space Telescope Wide Field Camera 3 to detect emission-line galaxies over 0.5 < z < 2.3. High-resolution (R~5000) follow-up spectroscopy with Magellan FIRE over 1.0--2.5 microns resolves important rest-frame optical emission lines, allowing us to measure physical properties such as dust obscuration, metal abundance, star formation rate, ionization parameter, and emission line kinematics. We also analyze the properties of composite spectra derived from the FIRE-observed sample. With this relatively large sample of rest-frame optical spectra we can make statistical inferences about the population of emission-line galaxies at z~2. We find that the galaxies are low metallicity (Z~1/5-1/2 Z_solar) as determined from the R23 calibration. The galaxies are low dust extinction on average (E(B-V)~0.2) but with significant scatter. The dust-corrected H-alpha star formation rates range from ~10--150 M_sun yr^-1 with a mean of 50 M_sun~yr^-1. The average ionization parameter for the sample, log U ~ -2.5, is higher than typically found for star-forming galaxies in the local universe but consistent with those found in more intense starbursting regions in galaxies such as M82. Emission line velocity dispersions are measured to be 71 +- 38 km s^-1, in good agreement with other studies that have probed the H-alpha kinematics of star-forming galaxies at similar redshift. The galaxies are compact, with half-light radii of < 2 kpc, and ~50% show evidence for multiple structures or asymmetries in the WFC3 imaging. Based on the line velocity dispersions and the location of the galaxies on BPT diagnostic plots, there is little evidence for significant AGN contribution to most emission-line galaxies at z~2.

227.04 – Simulating Future Near-Infrared Grism Spectroscopy Using The WFC3 Infrared Spectroscopic Parallels (WISP)

James W. Colbert[1], Harry I. Teplitz[1], Hakim Atek[4], Andrew J. Bunker[5], Marc Rafelski[1], Claudia Scarlata[2], Nathaniel Ross[3], Matthew A. Malkan[3], Alejandro Bedregal[6], Alberto Dominguez[7], Alan Dressler[8], Alaina L. Henry[9], Crystal L. Martin[10], Daniel Masters[7], Patrick J. McCarthy[8], Brian D. Siana[7]
1. Caltech, Pasadena, CA, United States. 2. University of Minnesota, Minneapolis, MN, United States. 3. University of California, Los Angeles, Los Angeles, CA, United States. 4. Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland. 5. University of Oxford, Oxford, United Kingdom. 6. Tufts University, Medford, MA, United States. 7. University of California, Riverside, Riverside, CA, United States. 8. Observatories of Carnegie Institution for Science, Pasadena, CA, United States. 9. Goddard Space Flight Center, Greenbelt, MD, United States. 10. University of California, Santa Barbara, Santa Barbara, CA, United States.

We present near-infrared emission line counts and luminosity functions from the HST WFC3 Infrared Spectroscopic Parallels (WISP) program for 29 fields observed using both the G102 and G141 grism. Using these derived emission line counts we make predictions for future space missions, like WFIRST, that will make extensive use of slitless grism spectroscopy in the near-IR over large areas of sky. The WISP survey is sensitive to fainter flux levels (3-5x10^-17 ergs/s/cm2) than the near-infrared grism missions aimed at baryonic acoustic oscillation cosmology (1-4x10^-16 ergs/s/cm2), allowing us to both investigate the fainter emission lines the large area surveys will be missing and make count predictions for the deeper grism pointings that are likely to be done over smaller areas. Cumulative number counts of 0.7<z<1.5 galaxies reach 10,000 square degrees above an H-alpha flux of 2x10^{-16} ergs/s/cm2. Galaxies with low H-alpha/[OIII] ratios are very rare at the brighter fluxes that future near-infrared grism surveys will probe; our survey finds no galaxies with H-alpha/[OIII < 0.95 that have H-alpha flux greater than 3x10^-16 ergs/s/cm2. We find good agreement between our derived luminosity functions and those from narrow band H-alpha surveys, like those of HiZELS (Sobral et al. 2013) and New Halpha (Ly et. 2011). The evolution in both the H-alpha luminosity function from z=0.3-1.5 and the [OIII] luminosity function from z=0.7-2.3 is almost entirely in the L* parameter, which steadily increases with redshift over those ranges. We will also present simulations of future large area near-infrared grism spectroscopy, based on the observed distributions of emission line fluxes, galaxy sizes, redshifts, H-alpha/[OIII] ratios, and equivalent widths seen in the WISP survey.

227.05 – Science Highlights from the 3D-HST Survey

Ivelina G. Momcheva[1]
1. Yale Univeristy, New Haven, CT, United States.
Contributing teams: 3D-HST Survey Team

3D-HST is a 248-orbit spectroscopic survey with the Hubble Space Telescope designed to study galaxy evolution at z>1. Providing the critical third dimension - redshift - via slitless optical and near-IR grism spectra, 3D-HST opens new possibilities for science and discovery in the deep extragalactic fields AEGIS, COSMOS, GOODS-S and UKIDSS-UDS. With

observations now completed, I will review the status of the survey and the plans of the team to make data products available to the community. We have combined the grism observations with archival data to create an unique dataset which incorporates > 1000 HST orbits. I will also present some science highlights from the survey. These include tracing the growth of Milky Way-like galaxies since z~2.5, investigating the star formation rates of quiescent galaxies at 0.3 < z < 2.5, a detailed analysis of resolved stellar populations patterns of galaxies and studying the properties of dust in star-forming galaxies at z~1.

227.06D – Recently Quenched Galaxies at z=2 in the 3D-HST Survey

Katherine E. Whitaker[1], Pieter G. Van Dokkum[2], Gabriel Brammer[3], Ivelina G. Momcheva[2], Rosalind Skelton[4], Marijn Franx[5]
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Contributing teams: 3D-HST collaboration

The process by which actively star-forming galaxies quench and migrate to form the well-defined color-mass relation, known as the "red sequence" is not well understood. We present direct evidence that the massive end of the red sequence is most-rapidly building up at z=2 when the universe was only 3 billion years old, with an influx of young recently quenched galaxies that are almost non-existent at z<1. Presenting recent results from the 3D-HST survey, we show that these recently quenched galaxies at z=2 have spectroscopic ages of 0.9 billion years and more compact sizes than older, redder quiescent galaxies. We further show that although the median stacked spectra of distant quiescent galaxies is dominated by an evolved stellar population, we see evidence for [OIII] and Hbeta emission. This emission is more centrally-concentrated than the continuum, indicating residual central star formation or nuclear activity. We interpret these observational results in the context of current galaxy formation and evolution theories.

227.07 – Star formation rates and extinction at z=1-2 from the AGHAST HST infrared grism survey

Benjamin J. Weiner[1]
1. University of Arizona, Tucson, AZ, United States.
Contributing teams: AGHAST team

At redshifts z=1-2, during the peak of the cosmic star formation rate density, galaxies have much higher SFRs than typical today. The physical processes driving high-SFR galaxies at high-z may be different than those responsible for high-SFR galaxies today: local very IR-luminous galaxies (LIRGs/ULIRGs) are typically mergers and have very compact, highy extincted regions of star formation, but this is more controversial at high redshift. I will discuss results from the AGHAST survey, a HST WFC3 infrared slitles grism spectroscopic survey of the GOODS-N field. HST grism spectroscopy provides a high multiplex and stable throughput in the infrared, yielding redshifts and good flux measurements for emission lines, including H-alpha, [O III] and H-beta. These allow measuring redshifts for optically faint galaxies and fluxes of nebular emission lines in the near-IR for comparison to low-z calibrations. We compare nebular extinction from the Balmer decrement and star formation rates from H-alpha to UV and far-IR measures, testing the calibration and reliability of SFRs and the nature of star-forming galaxies. We find that although some highly reddened galaxies exist, galaxies at the LIRG and ULIRG thresholds at z=1-2 often show spatially resolved, spread out star formation. We discuss the population of highly absorbed vs. less extincted galaxies, in terms of H-alpha to far-IR, and its relation to global galaxy properties.

228 – Extrasolar Planet Detection - Kepler Mission and Microlensing Surveys

Oral Session – Maryland Ballroom A – 07 Jan 2014 02:00 pm to 03:30 pm

228.01 – The Kepler Mission on Two Reaction Wheels is K2

Michael R. Haas[1], Thomas Barclay[4,1], Natalie M. Batalha[1], Steve Bryson[1], Douglas A. Caldwell[2,1], Jennifer Campbell[3,1], Jeffrey Coughlin[2,1], Steve B. Howell[1], Jon M. Jenkins[2,1], Todd C. Klaus[3,1], Fergal Mullally[2,1], Dwight T. Sanderfer[1], Charles K. Sobeck[1], Martin D. Still[4,1], John Troeltzsch[5], Joseph D. Twicken[2,1]

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Although data collection for the original Kepler mission is complete, a repurposed Kepler has the potential to discover many hundreds of new, small exoplanets around low-mass stars located in or near the ecliptic plane. This repurposing of the Kepler spacecraft, dubbed "K2," seeks to maximize photometric performance using its two operational reaction wheels by observing in the ecliptic plane where solar torques can be carefully balanced to minimize boresight roll. The K2 mission shows great promise and, once approved, will observe many different fields during a sequence of two- to three-month campaigns over the next few years. Like the original Kepler mission, K2 has many challenges, but is anticipated to be well worth the climb scientifically. K2 can observe many thousands of new sources during each campaign and hundreds of thousands of new sources over its lifetime. In addition to its continued search for exoplanets, the K2 mission will provide access to a wide variety of scientifically interesting targets that include young and variable stars, open clusters of differing ages, star-forming regions, supernovae, white dwarfs, microlensing events, solar system objects, AGNs, normal galaxies, and the Galactic Center. Performance testing began in September, 2013, and has continued throughout the fall and early winter. The results of the first ecliptic-plane tests are described and used to predict photometric performance. A trade study reveals the likely number of targets, cadence durations, initial fields of view, and planned observing strategies. K2 is an exciting new mission that addresses a wide variety of scientific questions with expanded opportunities for community participation.

228.02 – The Kepler Q1-Q12 Planet Candidate Catalogue

Jason Rowe[1,2]
1. NASA Ames Recenter Center, Moffett Field, CA, United States. 2. SETI Institute, Moffett Field, CA, United States.
Contributing teams: The Kepler Team

An update on the Kepler Planetary Candidate Catalogue (http://exoplanetarchive.ipac.caltech.edu /docs/Kepler_KOI_docs.html) will be presented that incorporates results of three years of nearly continuous, high precision photometry. Through a series of tests to exclude false-positives, primarily caused by eclipsing binary stars, over 900 additional planetary candidates have been discovered. Approximately 50 of the new candidates have equilibrium temperatures less than 300 K. More than 400 of the new planetary candidates have a radius less that 1.5 Rearth. A handful of the new candidates meet both criteria, roughly doubling the number of near Earth analogs.

228.03 – An Estimate of Eta-Earth, Based on a New Analysis of Kepler Completeness

Wesley A. Traub[1]
1. Jet Propulsion Laboratory, Pasadena, CA, United States.

Projecting Kepler's planet frequency as a function of planet radius and period depends sensitively on an accurate estimate of the detection completeness. This is particularly important for terrestrial planets in habitable-zone orbits, because it is precisely in this regime (small radii, long periods) where photon noise makes such detections essentially impossible below a fairly sharply-defined threshold signal level. I show that this threshold can be estimated from the existing data, and that by taking this cutoff into account, the distribution of planets, as a function of radius and period, can be estimated with minimal bias. Extending this function to terrestrial planets in habitable-zone orbits yields an estimate of eta-sub-Earth.

228.04 – Bridging the Habitable Gap: Combining Kepler and AFTA-WFIRST to Obtain a More Robust Estimate of ?_Earth

Matthew Penny[1], B. S. Gaudi[1]
1. Ohio State University, Columbus, OH, United States.

One of the primary goals of the Kepler mission is to determine the frequency of habitable terrestrial planets around sunlike stars (?_Earth). While there have already been estimates of the frequency of habitable planets orbiting M-dwarfs, the longer periods and larger-than-expected activity intrinsic stellar variability may make the estimates of ?_Earth for sunlike stars substantially more uncertain. The gravitational microlensing survey of the AFTA-WFIRST mission will complement Kepler's search for warm and hot planets by characterizing the frequency of cold planets. While the majority of the host stars of the microlensing survey will be low-mass stars, AFTA-WFIRST is most sensitive to habitable planets around the sunlike hosts. I will introduce the microlensing survey of AFTA-WFIRST, and then focus on its ability to detect habitable planets and its synergies with Kepler. Specifically, I will discuss how results on the abundances of planets from Kepler and AFTA-WFIRST might be combined to interpolate into the habitable zone and thus obtain a more robust measurement of ?_Earth.

228.05 – Enabling an Exoplanet Census with the Korean Microlensing Telescope Network: Optimal Survey Strategies and Predicted Planet Yields

Calen B. Henderson[1], B. S. Gaudi[1], Cheongho Han[2], David Nataf[3], Jan Skowron[4], Matthew Penny[1], Andrew Gould[1]

1. The Ohio State University, Columbus, OH, United States. 2. Chungbuk National University, Cheongju, Korea, Republic of. 3. Australian National University, Weston Creek, ACT, Australia. 4. Warsaw University Observatory, Warsaw, Poland.

The unique sensitivity of gravitational microlensing to low-mass planets at or beyond the snow line makes it an indispensable tool for understanding the distribution and formation mechanisms of exoplanets. The Korean Microlensing Telescope

Network (KMTNet) consists of three 1.6m telescopes each with a 4 $\deg^2$ field of view and will be dedicated to monitoring the Galactic Bulge in order to detect exoplanets via gravitational microlensing. With its relatively large aperture, large field of view, high cadence, and near-complete longitudinal coverage of the Galactic Bulge for much of the microlensing observing season (early March through late October), KMTNet will provide the opportunity to probe exoplanet demographics in an unbiased and automated way. Here we present detailed simulations that optimize the observing strategy and predict the planetary yields of KMTNet for planets with mass greater than that of Mars, including those for solivagant planets.

228.06 – New Programs to Promote Mass Measurements and Planet Discovery via Gravitational Lensing Events

Rosanne Di Stefano[1], William Bryk[2], Idan Ginsburg[1], Nikhil Kunapuli[3], Max Murphy[1], Antonia Oprescu[1], Francis Primini[1], Ben Tunbridge[1]

1. Harvard-Smithsonian CfA, Cambridge, MA, United States. 2. Ramaz Upper School , New York, NY, United States. 3. Bridgewater-Raritan High School, Bridgewater, NJ, United States.

Gravitational lensing events are opportunities to discover dim astronomical masses. Furthermore, whether or not the presence of the lens was known before the event, the lensing light curve provides information about the mass of the lens and about whether the lens has stellar or planetary companions. Until now, however, we have been able to derive detailed information about the lens system in fewer than one percent of the more than 10,000 already-identified candidate lensing events. In this talk we will describe an ongoing program to learn more about past lensing events, and a new program that will enhance the monitoring of future events in order to learn even more about the lenses. The programs to study new events have two components. The first component starts with events discovered by lensing monitoring teams, such as the OGLE and MOA surveys. By identifying catalogued counterparts to the events and implementing model fits that include a variety of physical effects, we can identify possible nearby-lens events that will be productive targets for enhanced monitoring. The second component consists of predicted close passages between a foreground and background star. These provide opportunities to search for evidence of lensing by planets of the foreground star. We describe planned investigations of both types to take place in 2014, and invite community participation.

229 – Extrasolar Planet Detection - Occultations, Coronagraphy, and Astrometry

Oral Session – National Harbor 13 – 07 Jan 2014 02:00 pm to 03:30 pm

229.01D – Laboratory Verification of Occulter Contrast Performance and Formation Flight

Dan Sirbu[1]

1. Princeton University, Princeton, NJ, United States.

Direct imaging of an exo-Earth is a difficult technical challenge. First, the intensity ratio between the parent star and its dim, rocky planetary companion is expected to be ten billion times. Additionally, for a planetary companion in the habitable zone the angular separation to the star is very small, such that only nearby stars are feasible targets. An external occulter is a spacecraft that is flown in formation with the observing space telescope and blocks starlight prior to the entrance pupil. Its shape must be specially designed to control for diffraction and be tolerant of errors such as misalignment, manufacturing, and deformations. In this dissertation, we present laboratory results pertaining to the optical verification of the contrast performance of a scaled occulter and implementation of an algorithm for the alignment of the telescope in the shadow of the occulter. The experimental testbed is scaled from space dimensions to the laboratory by maintaining constant Fresnel numbers while preserving an identical diffraction integral. We present monochromatic results in the image plane showing contrast better than 10 orders of magnitude, consistent with the level required for imaging an Exo-earth, and obtained using an optimized occulter shape. We compare these results to a baseline case using a circular occulter and to the theoretical predictions. Additionally, we address the principal technical challenge in the formation flight problem through demonstration of an alignment algorithm that is based on out-of-band leaked light. Such leaked light can be used a map to estimate the location of the telescope in the shadow and perform fine alignment during science observations.

229.02 – The Gemini Planet Imager

Bruce Macintosh[1,2]

1. LLNL, Livermore, CA, United States. 2. Stanford University, Stanford, CA, United States. Contributing teams: Gemini Planet Imager instrument team, Gemini Planet Imager Exoplanet Survey, Gemini Observatory

The Gemini Planet Imager (GPI) is a next-generation adaptive optics coronagraph designed for direct imaging and spectroscopy of warm self-luminous extrasolar planets and polarimetry of circumstellar disks. It is the first such facility-class instrument deployed on a 8-m telescope, designed to be an order of magnitude more sensitive than existing high-contrast imaging capabilities. GPI has completed laboratory integration and testing, shipped to Gemini South, and is scheduled for first light in November 2013. I will present an overview of the GPI design and measured performance, and any first light results, including a public release of fully reduced data for selected targets. in 2014, GPI will be available for science validation, and in the second half of 2014, a large-scale exoplanet survey campaign will begin.

229.03 – Archival Legacy Investigation of Circumstellar Environments (ALICE): Overview and First Results

Remi Soummer[1], Travis S. Barman[1], Christine Chen[1], Elodie Choquet[1], Thomas Comeau[1], John H. Debes[1], David A. Golimowski[1,3], J. Brendan Hagan[1], Dean C. Hines[1], Sean Lonsdale[2], Christian Marois[7], Dimitri Mawet[6], Tushar Mittal[1], Margaret Moerchen[1], Mamadou N'Diaye[1], Marshall D. Perrin[1], Laurent Pueyo[5], Abhijith Rajan[1], Iain N. Reid[4], Glenn Schneider[1], Schulyer Wolff[4]

1. Space Telescope Science Institute, Baltimore, MD, United States. 2. HIA-NRC, Victoria, BC, Canada. 3. Purdue University, Lafayette, IN, United States. 4. University of Arizona, Tucson, AZ, United States. 5. Arizona State University, Phoenix, AZ, United States. 6. Berkeley, Berkeley, CA, United States. 7. ESO, La Serena, Chile.

The Archival Legacy Investigation of Circumstellar Environments (ALICE) project ((HST/AR program 12652) is currently conducting a comprehensive and consistent reprocessing of HST-NICMOS coronagraphic survey data to search for point sources and disks using advanced PSF subtraction. This project has already been very successful with numerous detections of previously unseen point sources and several debris disks that we are currently following up by multiple avenues. We give an overview of the project including preliminary scientific results with companion candidates, improved images of known disks, and first scattered light image of several disks. ALICE will deliver high-level science products (HLSPs) to the community through the MAST archive at STScI. The goal is to define a HLSP standard that can be applicable to other projects including ground-based (e.g., Gemini Planet Imager), and future space instruments (e.g., JWST). The ALICE pipeline takes full advantage of the LAPLACE PSF library (Schneider et al. 2012) for coronagraphic data, which provides enhanced calibration of NICMOS coronagraphic data and is available from the MAST archive.

229.04 – On-Sky Tests of High Precision Astrometry and Implications for Exoplanet Mass Measurement

Stephen Ammons[1], Bruce Macintosh[1], Dmitry Savransky[1], Christian Marois[4], Benoit Neichel[5], Olivier Guyon[2], Eduardo Bendek[3]

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In the past two decades, hundreds of exoplanets have been discovered orbiting solar-type stars. Although many are low-mass — and potentially habitable — 98% of known exoplanets are farther than 10 parsecs away, making further study with spectroscopy or imaging difficult. Searching for exoplanets around lower-mass hosts, including M stars and brown dwarfs, is key to finding nearby exoplanets that are more valuable for future study. Brown dwarfs are ubiquitous in our solar "backyard"; however, due to their intrinsic faintness, no progress has been made in detecting planets around brown dwarfs — and a complete understanding of planet formation on all scales will require such detections. Astrometry is a viable technique for discovering or measuring the masses of exoplanets orbiting nearby low mass stars and brown dwarfs. However, only large telescopes observing in the infrared can achieve the astrometric precision necessary to do so, and furthermore, MCAO systems should deliver the best available relative astrometric precision from the ground. We present results from two on-sky pathfinder instruments characterizing astrometric errors in MCAO systems. The first is an astrometric monitoring program of bright stars with the Gemini MCAO system. We show that the astrometric precision in sparse fields reaches a noise floor at 0.4 milliarcseconds for single epochs over an 85" field, but is limited to ~1 mas over multiple epochs due to systematic errors. The second pathfinder is an on-sky test of the diffractive pupil concept on a 1-meter telescope at Lick Observatory, intended to reduce astrometric systematic errors by calibrating changing optical distortion (Guyon et al. 2012). These data reveal PSF modeling systematics of one thousandth of the star FWHM (1 mas) for individual stars. We show that the diffractive pupil stabilizes the instrumental distortion to at least the precision of the experiment (~1 mas over 3').

229.05 – Kappa Andromedae B: New Constraints on the Companion Mass, System Age and Further Multiplicity

Sasha Hinkley[1], Laurent Pueyo[2], Jacqueline K. Faherty[3], Ben R. Oppenheimer[4], Eric E. Mamajek[5], Adam L. Kraus[6], Emily L. Rice[7, 3], Michael Ireland[8, 9], Trevor David[1], Lynne Hillenbrand[1], Gautam Vasisht[10], Eric Cady[10], Douglas Brenner[4], Aaron Veicht[4], Ricky Nilsson[4], Neil Zimmerman[11], Ian Parry[12], Charles A. Beichman[13], Richard Dekany[14], Lewis C. Roberts[10], Christoph Baranec[14], Justin R. Crepp[15]

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I will report new results on the companion to the B9IV star kappa Andromedae, originally detected using adaptive optics and coronagraphy at Subaru Observatory, with an initially reported mass of 12.8 Jupiter masses. I will present the first spectrum of the companion, kappa And B, using the Project 1640 high-contrast imaging platform at Palomar Observatory. Comparison of our low-resolution YJH-band spectra to empirical brown dwarf spectra as well as synthetic models suggests an early-L spectral type and an effective temperature of 2000 K. Further, we use previously reported log(g) and effective temperature measurements of the host star to argue that the kappa Andromedae system has an isochronal age of 220 +/- 100 Myr, older than the 30 Myr age reported previously. This interpretation of an older age is corroborated by the photometric properties of kappa Andromedae B, which appear to be marginally inconsistent with other 10-100 Myr low-gravity L-dwarfs for the spectral type range we derive. In addition, we use Keck aperture masking interferometry combined with published radial velocity measurements to rule out the existence of any tight stellar companions to kappa Andromedae A that might be responsible for the system's overluminosity. Further, we show that luminosity enhancements due to a nearly ``pole-on'' viewing angle coupled with extremely rapid rotation is unlikely. Kappa Andromedae A is thus consistent with its slightly evolved luminosity class (IV) and we propose here that kappa Andromedae, with a revised age of 220 +/- 100 Myr, is an interloper to the 30 Myr Columba association with which it was previously associated. The photometric and spectroscopic evidence for kappa Andromedae B combined with our re-assesment of the system age implies a companion mass more consistent with a brown dwarf than a planetary mass companion.

230 – Extrasolar Planet: Spectroscopy, Metallicity, and Composition

Oral Session – Maryland Ballroom B – 07 Jan 2014 02:00 pm to 03:30 pm

230.01D – Elemental Compositions of Extrasolar Planetesimals

Siyi Xu[1], Michael Jura[1]
1. UCLA, Los Angeles, CA, United States.

The composition of extrasolar rocky planets is essential for understanding the formation and evolution of these alien worlds. Studying externally-polluted white dwarfs provides the only method to directly measure the elemental compositions of extrasolar planetesimals, the building blocks of planets. The standard model is that some planetesimals can survive to the white dwarf phase, get perturbed, enter into the tidal radius of the white dwarf and get accreted, polluting its pure hydrogen or helium atmosphere. We have been performing high-resolution spectroscopic observations on a number of polluted white dwarfs to measure the bulk compositions of the accreted objects. To have a full picture of the abundance pattern, we gathered data from both Keck/HIRES and HST/COS. I will present the analysis for one of the most interesting objects -- G29-38. It is the first white dwarf identified with an infrared excess from debris of pulverized planetesimals and among the very first identified polluted hydrogen atmosphere white dwarfs. Our analysis indicates that the accreted extrasolar planetesimal is enhanced in refractory elements and depleted in volatile elements. A detailed comparison with solar system objects show that the observed composition can be best interpreted as a blend of chondritic object with some refractory-rich material, a result from post-nebular processing. When all polluted white dwarfs are viewed as an ensemble, we find that the elemental compositions of accreted extrasolar planetesimals resemble to those of solar system objects to zeroth order. (i) The big four elements, O, Fe, Mg and Si are also dominant. Objects with exotic compositions, e.g. diamond planets and refractory-dominated planets, are yet to be found. (ii) Volatiles, such as carbon and water, are only trace constituents. In terms of bulk composition, solar system objects are essentially normal.

230.02 – The Intrinsic EUV, Lyman-alpha, and UV Emission from Exoplanet Host Stars

Jeffrey Linsky[1], Kevin France[2], Juan Fontenla[3]
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The chemical composition and mass loss from exoplanet atmospheres is driven largely by the ultraviolet and extreme ultraviolet (EUV) radiation from their host stars. In particular, such important molecules as H_2O, CO_2, and CH_4 are photodissociated primarily by radiation in the Lyman-alpha line, and planetary exospheres are heated primarily by EUV radiation from the host star, producing expansion and mass loss. Unfortunately, most of the host star radiation in the Lyman-alpha line is removed by hydrogen in the interstellar medium, and the EUV emission between 400 and 912 Angstroms is absorbed by interstellar hydrogen. We have developed a variety of techniques for inferring the intrinsic Lyman-alpha and EUV emission from main sequence stars with spectral types F5 to M5. We find that the ratios of the EUV flux to Lyman-alpha and the Lyman-alpha flux to other emission lines are relatively insensitive to spectral type and activity. We therefore propose formulae for estimating the intrinsic emission from exoplanet host stars. We present results from our HST observing program MUSCLES that provides near-UV and far-UV spectra of M dwarf exoplanet host stars. We also present a preliminary non-LTE chromosphere model for an M dwarf host star. This combination of HST spectra, host star models, and estimated intrinsic Lyman-alpha and EUV emission provides essential input for the computation of photochemical models of exoplanet atmospheres. This work is supported by the Space Telescope Science Institute and NASA grants.

230.03 – Planet-Metallicity Correlation For Planets of Different Sizes

Ji Wang[1]
1. Yale University, New Haven, CT, United States.

Metallicity of exoplanet systems can serve as a critical diagnosis on the planet formation mechanisms. Previous studies took followup observations to measure metallicity of a sample of Kepler planet candidates host stars. It is shown in these studies that planet-metallicity exists for large planets (RP ? 4 RE), but there is a lack of such correlation for smaller planets. We use a sample 1166 multi-planet candidates from Kepler Objects of Interest and with metallicity estimation from Kepler Input Catalog to study the planet-metallicity correlation. The sample is a factor of 3-4 larger than those in previous studies. Unlike previous studies, we consider both detections and non-detections of planet candidates. We use a ratio between the number of planet candidates and the number of searched stars (planet-star ratio) in a RP [Fe/H] parameter space as an estimation of planet frequency. For orbital period within 100 days, we found a strong planet-metallicity correlation for gas giant planets (5 RE ≤ RP ≤ 22 RE). Planet frequency is 2.6 times higher for the super-solar metallicity group ([Fe/H] ? 0.0) than the sub-solar metallicity group ([Fe/H] ≤ 0.0). For Neptune-like planets (2 RE ≤ RP ≤ 5 RE), planet frequency for the metal-rich sample is 1.4 times higher than the metal-poor sample, but this conclusion depends on corrections for different stellar populations of two metallicity groups. Planet frequency correlation with metallicity for small-radii planets (RP ≤ 2 RE) is consistent with non-positive correlation.

230.04 – Detecting water at high-spectral resolution in hot Jupiter atmospheres

Jayne Birkby[1], Ignas Snellen[1], Remco de Kok[2], Matteo Brogi[1], Henriette Schwarz[1], Simon Albrecht[3], Ernst de Mooij[4]
1. Leiden Observatory, Leiden, Zuid Holland, Netherlands. 2. SRON, Utrecht, Holland, Netherlands. 3. MIT, Cambridge, MA, United States. 4. University of Toronto, Toronto, ON, Canada.

The robust determination of the chemical make-up of exoplanet atmospheres is crucial to understanding their structure, formation, and evolution, particularly in the case of the major carbon- and oxygen-bearing species. We present ground-based high-resolution spectra from CRIRES/VLT at 3.2 microns of several transiting and non-transiting hot Jupiter atmospheres (51 Peg b, tau Boo b, HD 209458 b), in which we have searched for the radial velocity signature of water, methane and carbon dioxide molecules in the planetary atmospheric spectra. We compare the results of our search with the detections of CO already reported in these hot Jupiter atmospheres, and discuss their temperature-pressure profiles and relative abundance ratios. Preliminary results indicate a significant abundance of water in 51 Peg b, consistent with tentative reports of water at 2.3 microns and suggest an oxygen-rich atmosphere.

230.05 – Transmission Spectroscopy of the Super-Earth GJ 1214b

Laura Kreidberg[1]
1. University of Chicago, Chicago, IL, United States.

We present results from an intensive observational campaign to study the atmosphere of the super-Earth exoplanet GJ 1214b. We observed 15 transits of the planet with the WFC3 instrument on the Hubble Space Telescope. With these data, we measure the transmission spectrum to unprecedented precision in the near-infrared. Previous measurements of the spectrum required either high-altitude clouds in the atmosphere or a high mean molecular weight composition (e.g., pure water vapor). Our results definitively resolve this ambiguity. We also present preliminary results of a Gemini program to measure the transmission spectrum in the blue optical.

230.06 – The Power of High Resolution Exoplanet Transmission Spectroscopy -- Constraining Winds, Circulation, Tidal Locking, and Clouds

Eliza Kempton[1], Rosalba Perna[2], Kevin Heng[3], Emily Rauscher[4]
1. Grinnell College, Grinnell, IA, United States. 2. University of Colorado, Boulder, CO, United States. 3. ETH Institute for Astronomy, Zurich, Switzerland. 4. Princeton University, Princeton, NJ, United States.

Recent transmission spectrum observations of hot Jupiter exoplanets at high spectral resolution have led to reports of direct detection of orbital motion, as well as detection of molecular spectral features and high altitude winds. Motivated by these studies, we present high resolution transmission spectra of giant planet atmospheres from a coupled 3-D atmospheric dynamics and transmission spectrum model. Our model spectra allow us to explore the range of observational constraints that can be placed on physical properties of giant planet atmospheres using high resolution transmission spectra. These properties include day-to-night winds, planetary rotation speeds, atmospheric structure, and the presence of clouds. The detection of Doppler shifted spectral lines can reveal the nature of atmospheric circulation in the upper atmospheres of exoplanets as well as constraining whether these planets are truly tidally locked as many models would predict. We conclude that high resolution transmission spectra are a useful atmospheric diagnostic tool that is most strongly limited by the ability to obtain high signal-to-noise spectra. Observations with future 30-meter class telescopes will be able to produce the required high SNR observations to fully take advantage of the information provided by high resolution exoplanet transmission spectra.

230.07 – Revisited Transit Spectroscopy of Giant Exoplanets Using HST/NICMOS

Drake Deming[1], Ashlee N. Wilkins[1], Nikku Madhusudhan[2]
1. Univ. of Maryland, Bowie, MD, United States. 2. Yale University, New Haven, CT, United States.

Infrared transmission spectroscopy of the giant transiting exoplanets HD189733b and XO-1b using HST/NICMOS produced some of the first measurements of molecular absorptions in hot Jupiters. The molecules that were identified in the NICMOS spectra included water vapor, methane, and carbon dioxide. However, the NICMOS detections were subsequently challenged by Gibson et al. (2011) on the basis that the removal of instrumental signatures using a linear decorrelation technique was not reliable. Subsequently, transmission spectroscopy measurements in the 1.1-1.7 micron infrared region, using HST/WFC3, are proving to be robust and sensitive. The best WFC3 transmission spectroscopy now achieves a precision of better than 35 parts-per-million per wavelength channel at a spectral resolution of 0.05 microns. The WFC3 spectroscopy contradicts the published NICMOS results for planets and wavelength regions where they overlap. To illuminate this discrepancy, we are re-analyzing the NICMOS data, including some measurements not previously published, using numerical techniques

developed and proven for WFC3.

230.08 – Exoplanet Secondary Eclipses Using WFC3

Korey Haynes[1,2], Avi Mandell[2], Drake Deming[3]
1. George Mason University, Fairfax, VA, United States. 2. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 3. University of Maryland, College Park, College Park, MD, United States.

I present preliminary results for emission spectra of several transiting hot Jupiters observed with the Wide Field Camera 3 on HST. By observing exoplanets during occultation, constraints can be made on the temperature structure and overall energy budget of the planet's atmosphere. Of special interest is the presence or absence of the thermal inversion predicted in many hot Jupiters, as well as the day-night energy redistribution. Combining WFC3 spectral data with pre-existing Spitzer photometric data for these planets can help break model degeneracies and yield new insights into these highly irradiated planets.

231 – Galaxy Evolution in Groups/Clusters
Oral Session – National Harbor 2 – 07 Jan 2014 02:00 pm to 03:30 pm

231.01 – A Study of the Cold Gas and Stellar Populations of the Antlia Cluster with KAT-7 and WISE

Kelley Hess[1], Claude Carignan[1], Tom Jarrett[1], Sharmila Goedhart[2], Sean S. Passmoor[2], Eric M. Wilcots[3]
1. University of Cape Town, Rondebosch, South Africa. 2. SKA-SA, Cape Town, South Africa. 3. University of Wisconsin-Madison, Madison, WI, United States.

We present neutral hydrogen (HI) observations of the Antlia Galaxy Cluster from the Karoo Array Telescope (KAT-7), a MeerKAT/SKA pathfinder array in South Africa, and describe some of the data reduction challenges overcome by the science commissioning team. Antlia is the third most nearby, massive galaxy cluster, yet it is poorly studied because it lies at low Galactic latitude (l=+19'?) in the Southern hemisphere. We combine the KAT-7 HI data with WISE infrared observations to study the gaseous and stellar components of the galaxy population of this dynamically young system. The velocity information from KAT-7 allows us to confirm gas rich cluster members that lack optical spectroscopic redshifts. Antlia is an ideal target for KAT-7 spectral line commissioning because the recessional velocity of cluster members is not confused with Galactic hydrogen, and the telescope resolution is such that we recover the full HI flux of galaxies, while not suffering from source confusion. The WISE observations cut through Galactic extinction to provide a more complete census of cluster member candidates. Blind HI observations have shown that the presence of gas rich objects around the dense environments of clusters and massive groups is an excellent tracer of substructure, highlighting filaments where galaxies are being accreted within the dark matter halo. With two distinct concentrations of galaxies centered on each of two large elliptical galaxies, the cluster is likely still in the process of merging, making it an interesting target for environmentally driven galaxy evolution studies.

231.02 – The role of pre-processing in SDSS groups and clusters

Annie Hou[1, 2], Laura C. Parker[2], William E. Harris[2]
1. KIAS, Seoul, Korea, Republic of. 2. McMaster University, Hamilton, ON, Canada.

We investigate the importance of pre-processing in the observed quenched fraction of rich group and cluster galaxies from the SDSS-DR7 Yang et al. (2007) group catalogue in the redshift range of $0:01 < z < 0:045$. A combination of the Dressler-Shectman statistic and the group member velocity distribution is used to identify subhaloes within the group. On average the fraction of galaxies that reside in subhaloes is a strong function of host halo mass where more massive systems, such as clusters, have a higher fraction of subhaloes both in the overall galaxy and infall populations. Comparison of the properties of galaxies that reside in subhaloes to those that do not shows that beyond the virial radius (r >~ 2r200) galaxies in the subhalo population differ from the non-subhalo population. In particular, the quiescent fraction is higher in subhalo galaxies with respect to both the field and non-subhalo galaxies. At these large radii, we find that the majority of galaxies (~80%) belong to the infall population. Therefore, we attribute the enhanced quenching to infalling subhalo galaxies, indicating that pre-processing has occurred in the subhalo population. We conclude that pre-processing plays a signicant role in the observed quiescent fraction, but only for the most massive (Mhalo > 10^14.5 Msun) systems in our sample.

231.03D – Spatio-Temporal Sequencing Of Mass Dependent Galaxy Transformation Mechanisms In The Complex Environment Of SuperGroup Abell 1882

Aparajita Sengupta[1], William C. Keel[1], Glenn E. Morrison[2, 3], Rogier A. Windhorst[4], Brent Smith[4]
1. Physics and Astronomy, University of Alabama, TUSCALOOSA, AL, United States. 2. University of Hawaii, Honolulu, HI, United States. 3. Canada-France-Hawaii Telescope (CFHT) Corp., Kamuela, HI, United States. 4. Arizona State University, Tempe, AZ, United States.

We present our data and results from the panchromatic photometry and optical spectrometry of the nearest filamentary large scale structure and a cluster-precursor, SuperGroup Abell 1882. We find that the galaxy color and morphology tie very strongly with local galaxy density even in a complex structure like Abell 1882. We identify the projected radial distance from the assumed center as a second order evolutionary driver. Our major results indicate that there is a strong dependence of galaxy transformations on the galaxy mass. We have found that the thoroughly quenched low mass galaxies are confined to the groups, whereas there are evidences of intermediate mass quenched galaxies even in the far outskirts. We conclude that mass-dependent evolutionary mechanisms quench galaxies at different spatial scales. The starburst galaxies and post-starburst galaxies in this structure exhibit a spatio-temporal sequence. We have also estimated a timescale for the dwarf galaxies that are quenched close to the group environment. We identify a starburst population preferentially occurring within the filaments, at least a subset of which must be progenitors of the quenched galaxies at the core of Abell 1882, indicating a higher degree of preprocessing within the filaments as compared to that in the field.

231.04 – Exploring the interconnectedness of halo mass, stellar mass, and environment of galaxies

Genevieve Shattow[1], Darren Croton[2]
1. Swinburne University of Technology, Hawthorn, VIC, Australia. 2. Swinburne University of Technology, Hawthorn, VIC, Australia.

In this talk I will discuss new results from the SDSS and the Theoretical Astrophysical Observatory where we measure the halo mass of galaxies as a function of their large-scale environment, defined by over-density on a 5Mpc scale. We consider this "environmental clustering" as a function of various galaxy properties, including colour and luminosity. We find interesting correlations - some expected, and others new. Our results indicate how galaxies at fixed stellar mass occupy different mass halos in low, median and high density environments within the large-scale structure.

231.05D – The Spitzer-South Pole Telescope Survey: Linking galaxies and haloes at z=1.5

Jesus Martinez-Manso[1], Anthony H. Gonzalez[1], Matthew Ashby[2], S. A. Stanford[3], Mark Brodwin[4], Gilbert P. Holder[5]
1. University of Florida, Gainesville, FL, United States. 2. Harvard CfA, Cambridge, MA, United States. 3. UC Davis, Davis, CA, United States. 4. University of Missouri, Kansas City, KS, United States. 5. McGill University, Montreal, QC, Canada.

We present results from the clustering of high redshift galaxies in the recently completed 94 deg^2 Spitzer-SPT Deep Field survey. Applying flux and color cuts on the mid-infrared bands allows us to efficiently select galaxies at z~1.5 in the stellar mass range 10^{10}-10^{11} M$_{TM}$, making this the largest survey used so far to study such distant population. We fit halo occupation distributions to our clustering data and determine the explicit dependence on the halo mass of the central galaxy's stellar mass and the satellite occupation. We measure a prominent peak in the stellar to halo mass ratio at a halo mass of $\log M_{peak}$ = 12.4±0.08, which is 4x higher than low redshift values and supports an evolving mass threshold above which star formation is quenched. We find values of the large scale bias in the range b_g=2-4 and satellite fractions f_{sat}~0.2, showing a clear and expected evolution compared to z=0 results. We also find that, above a given stellar mass limit, the fraction of galaxies that are in similar mass pairs is higher at z=1.5 than at z=0. In addition, we measure that such fraction increases slightly with the stellar mass limit at z=1.5, which is the opposite behavior than what is found at low redshift.

231.06D – How do galaxies populate dark matter halos across cosmic time?

David P. Palamara[1,2], Michael J. Brown[1], Buell Jannuzi[2], Martin White[3], Peder Norberg[4]
1. School of Physics, Monash University, Clayton, VIC, Australia. 2. University of Arizona, Tucson, AZ, United States. 3. University of California, Berkeley, Berkeley, CA, United States. 4. Durham Unversity, Durham City, Durham, United Kingdom.
Contributing teams: GAMA team, NDWFS team

To understand how galaxies grow within dark matter halos, we have used measurements of galaxy clustering to determine halo masses and halo occupation distributions for star-forming and passive galaxies. In the local universe, the majority of stellar mass is found in (passive) galaxies no longer growing significantly by in-situ star formation. However, most (by number) galaxies are actively forming stars. The spatial distribution of galaxies is a biased tracer of the underlying dark matter, which evolves by gravity alone, and these two broad class of galaxy tend to trace the dark matter differently. We have measured galaxy clustering as a function of mass, luminosity, colour and redshift. We use this to constrain the galaxy halo occupation distribution as a function of their physical properties. Using optical and infrared colors as a proxy for star formation, we select passive and star-forming galaxies in GAMA (z<0.4) and NDWFS Bootes (0.4<z<1.5), as a function of luminosity and stellar mass. GAMA and Bootes provide the largest area and depth to for their respective redshift ranges and survey type to date. We find, as others have, that passive galaxies occupy more massive halos than star-forming galaxies of the same luminosity and mass. Halo mass increases irrespective of the presence of star-formation as a function of luminosity and mass. We find that while the most massive local universe galaxies have not actively formed stars within the past ~7Gy, in general local passive galaxies have had active star-formation during this time.

232 – Laboratory Astrophysics
Oral Session – Maryland 1 – 07 Jan 2014 02:00 pm to 03:30 pm

232.01D – Improved Transition Probabilities for Fe-group Elements to Resolve Unexpected Trends in Metal-Poor Stars

Michael P. Wood[1]

1. University of Wisconsin-Madison, Madison, WI, United States.

Stellar abundances as a function of metallicity provide valuable information regarding the nucleosynthetic history of chemical elements in the Galaxy. Of particular importance are old, metal-poor stars, whose abundances provide a "fossil record" of the nucleosynthetic processes at work in the early Galaxy. The relative abundances of iron (Fe)-group elements provide perhaps the best constraints on the supernova properties of the early generations of stars. Studies of Fe-group abundances in metal-poor stars have found unexpected trends in relative abundance ratios versus metallicity down to metallicities of -4. These results have not been reconciled with current models of Fe-group production in the early Galaxy, and while these trends may indicate a need to revisit these models, the possibility remains that they are manifestations of inaccurate atomic data and/or non-LTE and 3D effects in the photospheres of stars of interest. In order to address these possible explanations, an effort is underway to improve the quality of laboratory atomic transition probabilities for first and second spectra Fe-group lines. A new echelle spectrometer has been developed to complement existing Fourier transform spectrometer (FTS) data typically used in transition probability studies. This instrument is free from the multiplex noise of a FTS which can overwhelm the weak lines necessary for accurate abundance determinations on Fe-group elements. The use of this new spectrometer, combined with an independent calibration method, allows for the reduction of systematic uncertainties, which are often the dominant source of uncertainty for branching fraction measurements. Using this new more accurate laboratory atomic data will allow for searches of non-LTE effects using lines covering a wide range of wavelengths and line strengths. I will discuss the development of this new echelle spectrometer as well as highlight recent results in Ti and Ni, and point toward future work on V and other Fe-group elements. This work is supported by NASA grant NNX10AN93G.

232.02 – Benchmarking Charge Exchange Theory with Experiments Using an X-ray Calorimeter at an Electron Beam Ion Trap

Gabriele Betancourt-Martinez[1,2], Frederick S. Porter[2], Maurice A. Leutenegger[2], Gregory V. Brown[3], Peter Beiersdorfer[3]

1. University of Maryland, College Park, MD, United States. 2. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 3. Lawrence Livermore National Laboratory, Livermore, CA, United States.

Charge exchange occurs widely throughout the solar system, and also represents a significant contaminating foreground to all observations from low-Earth orbit. With the upcoming 2015 launch of the Astro-H X-ray satellite, which will produce the first high-resolution spectra of extended X-ray sources, it is crucial to improve our understanding of charge exchange spectra. Theoretical models of charge exchange spectra do not always accurately describe observations and require further experimental verification. To this end, we present X-ray spectra from charge exchange experiments performed with the Electron Beam Ion Trap (EBIT) facility at Lawrence Livermore National Laboratory, using the EBIT Calorimeter Spectrometer. We compare the relative strength of the high-n Lyman series emission while varying the ions and neutral gas. We show ion temperature measurements to disentangle the effects of variations in collision velocity. We find that empirical results vary widely with no clear correlation with current theory. We present experimental benchmarks that can be used to develop a more comprehensive and accurate theory.

232.03 – AtomDB 3.0: Atomic Data for Non-equilibrium Ionization Studies

Adam Foster[1], Randall K. Smith[1], Hiroya Yamaguchi[2,1], Li Ji[3], Jörn Wilms[4]

1. Harvard Smithsonian, CfA, Cambridge, MA, United States. 2. NASA GSFC, Greenbelt, MD, United States. 3. Purple Mountain Observatory, Nanjing, Jiangsu, China. 4. Friedrich-Alexander-Universität, Erlangen-Nürnberg, Bavaria, Germany.

Collisional plasmas outside of equilibrium exist in a range of astrophysical phenomena, most notably in solar flares and supernova remnants (SNRs). Discovery of strong recombination edges in several mixed-morphology SNRs (e.g. IC 443, W49B) have demonstrated the need for a model of not only ionizing, but also recombining non-equilibium ionization (NEI) plasma. We have developed new capabilities in AtomDB (www.atomdb.org), allowing modeling of NEI plasma in both equilibrium and non-equilibrium, including emission from all inner shell processes such as Kα and Kβ emission. In order to accurately model the NEI spectrum, we have compiled and benchmarked new rate coefficients for inner shell processes. We have also created XSPEC models for these, ready for use now. We show examples of these models for the SNR case, and discuss the implications of the new model. We also describe the new code libraries available for non-equilibrium ionization

232.04 – Madison Plasma Dynamo Experiment

Evdokiya Kostadinova[1,2], Cary Forest[2], Christopher Cooper[2], Martin Coquerel[2]
1. Furman University, Greeville, SC, United States. 2. University Of Wisconsin, Madison, Madison, WI, United States.

The Madison Plasma Dynamo Experiment (MPDX) is investigating the self-generation of magnetic fields and related processes in a large, weakly magnetized, fast flowing, and hot (conducting) plasma. The dynamo re-creates conditions highly similar to many astrophysical plasmas. Stars and other planets have dynamos, and so do galaxies and clusters of galaxies, which makes it extremely crucial for researchers in the field to carry out experiments in this previously uninvestigated plasma regime, which will help for the development of a comprehensive theory of how magnetic fields are generated in planets, the Sun and other stars. MPDX is a laboratory astrophysical experiment where 200,000-degree Fahrenheit plasma is confined within a three-meter diameter spherical aluminum vacuum chamber with the help of multiple tracks of cusp magnets covering the inside shell. The dynamo utilizes six robotic insertion sweep probes that are programmed to find any point inside the sphere by given radial and angular coordinates. This innovative mechanical system allows us to take measurements of the state variables in key points in the plasma flow and to better investigate its cosmic-like plasma behavior. The probes are able to autonomously calculate coordinate transformations, move in a two dimensional plane, and return information about their relative position. This makes them an extremely useful, highly accurate, and easily controlled tool for plasma analysis.

233 – Lenses & Waves II

Oral Session – National Harbor 12 – 07 Jan 2014 02:00 pm to 03:30 pm

233.01 – SALT Redshift Determinations of Herschel Discovered Strong Gravitational Lenses

Lerothodi Leeuw[1,2], Steve Crawford[3]

1. University of South Africa, Pretoria, Gauteng Province, South Africa. 2. SETI Institute, Mountain View, CA, United States. 3. South African Astronomical Observatory, Cape Town, Western Cape Province, South Africa.

Contributing teams: The Herschel-ATLAS Team

We present early results of the Southern African Large Telescope (SALT) observations of strong gravitational lenses. The lens systems were discovered by Herschel Space Observatory in large area maps conducted by the Herschel-ATLAS team and typically comprise a foreground optically-bright lensing galaxy and a background submm bright lensed galaxy. The SALT observations are aimed at determining the redshifts of the lensing galaxies and exploiting them to characterize the individual lensing systems and the sample, in conjunction with observations at other international telescope

233.02D – A new pixel-based method for analyzing spatially resolved, gravitationally lensed images

Amitpal S. Tagore[1], Charles R. Keeton[1], Andrew J. Baker[1]

1. Rutgers University, Piscataway, NJ, United States.

Gravitational lens modeling of spatially resolved sources is a challenging inverse problem that requires careful handling of parameter degeneracies. I describe a new pixel-based source reconstruction method and analyze statistical and systematic effects, including pixelization, noise, telescope pointing, and resolution. I show applications of the method to observations of two lensed, high-redshift galaxies. For SDSS J120602.09+514229.5 (also known as the Clone), a $z=2.001$ star-forming galaxy lensed by a foreground galaxy at $z=0.42$, the errors on the model are appropriately accounted for, and the results are in agreement with previous analyses. For SDSS J0901+1814 (J0901), a $z=2.26$ ultraluminous infrared star-forming galaxy lensed by a foreground group of galaxies at $z=0.35$, I constrain the lens model using CO rotational line maps of multiple velocity channels, in addition to optical and infrared data. The reconstructed velocity fields in the source plane make it possible to infer J0901's intrinsic dynamical mass and gas mass fraction. Combining the CO maps with H-alpha observations allows us to test the applicability of the local Kennicutt-Schmidt relation at high redshift.

233.03 – Fundamental Constants, New Physics and the Dark Energy Equation of State

Rodger I. Thompson[1]

1. Univ. of Arizona, Tucson, AZ, United States.

One of the most urgent quests in modern astrophysics and cosmology is the determination of the dark energy equation of state, w, as a function of time. Standard λCDM cosmology fixes w at -1 for all epochs of the universe, whereas, rolling scalar field cosmologies have values of w that evolve with time. Most rolling scalar fields also couple with the electromagnetic field to produce changes in the fundamental constants such as the fine structure constant α and the proton to electron mass ratio μ. If the strength of the coupling is given as ? then the change of the fundamental constants is proportional to the integral of $?^2(w+1)$ integrated over the interval of change. Note that the value of w does not have to change over time to alter the values of the fundamental constants, it just has to be different from -1. This talk examines the present state of limits on w and the variation of fundamental constants to evaluate the parameter space available to new cosmologies and physics. The current limits on the variation of the fundamental constants greatly restricts that space.

233.04 – Optimal Measurement of Dark Energy Parameters with Weak Gravitational Lensing Magnification

Michael Schneider[1, 2]

1. Lawrence Livermore Natl Lab, Livermore, CA, United States. 2. UC Davis, Davis, CA, United States.

I will present an estimator for the gravitational lensing magnification of galaxies by cosmological large-scale structure that minimizes systematic biases while optimizing the signal-to-noise ratio. The estimator is derived by solving the Limber equation for a redshift-dependent weighting of the foreground tracer that nulls either intrinsic clustering or gravitational lensing contributions to the cross-correlation function. While large numbers of galaxies are required to reduce the shot noise, future surveys such as the Large Synoptic Survey Telescope should be able to utilize lensing magnification as an independent probe of dark energy; yielding a Figure of Merit within 80% of that from cosmic shear.

233.05D – Gravitational lensing as a tool for cosmology: Sources of bias and techniques for achieving its full potential

Michael A. Troxel[1], Mustapha B. Ishak-Boushaki[1]

1. University of Texas at Dallas, Richardson, TX, United States.

Gravitational lensing has been identified as a critical tool in studying the evolution of large scale structure in the universe, as well as shedding light on the nature and influence of dark matter and dark energy. One of the primary systematic biases in weak lensing due to large scale structure (or cosmic shear) is the intrinsic alignment (IA) of galaxies, which poses a barrier to precision weak lensing measurements. Methods for identifying and removing its effects on cosmological information are key to the success of current and planned lensing surveys. We have expanded model-independent techniques to indirectly isolate and remove the IA contamination from the lensing signal. These self-calibration techniques take advantage of complimentary survey information to self-calibrate the lensing signal, which along with the unique lensing and IA geometry and separation dependencies, allow us to reconstruct the various IA correlations at the level of the spectrum and bispectrum. For cross-correlations, we have demonstrated that the self-calibration approach can reduce the IA bias over most relevant scale and redshift ranges by up to a factor of 10 or more. In the case of auto-correlations, we have demonstrated the feasibility of implementing the self-calibration for conservative estimates of photo-z accuracy in planned surveys. This could reduce a potential 10-20% bias in some cosmological information down to the 1-2% level. In both cases, the self-calibration has the added benefit of preserving the IA signal, that itself provides additional information which can be used in studying the formation and evolution of large scale structure in the universe. We have also investigated some impacts on kinematic and lensing information derived from the use of exact relativistic models for structures and cosmology with some level of anisotropies. We have found, for example, that ignoring substructure level anisotropies in structures could bias mass estimates by up to 10%.

234 – Reports from NASA's Astrophysics Program Analysis Groups

Special Session – Potomac Ballroom A – 07 Jan 2014 02:00 pm to 03:30 pm

This special session will report on the current activities of NASA's Program Analysis Groups (PAGs.) These groups serve as forums for soliciting and coordinating input and analysis from the scientific community in support of the Astrophysics Division's program objectives. This session will begin with an introduction to the PAGs by representatives from NASA Headquarters and then include reports on current activities from the Chairs of the Exoplanet Exploration PAG (ExoPAG), the Cosmic Origins PAG (COPAG), and Physics of the Cosmos PAG (PhysPAG).

234.01 – Overview of NASA Astrophysics Program Analysis Groups

Michael R. Garcia[1], Douglas M. Hudgins[1], Rita M. Sambruna[1]
1. Astrophysics , NASA HQ, Washington, DC, United States.

NASA Astrophysics Program Analysis Groups (PAGs) are responsible for facilitating and coordinating community input into the development and execution of NASAs three astrophysics science themes: Cosmic Origins (COPAG), Exoplanet Exploration (ExoPAG), and Physics of the Cosmos (PhysPAG). The PAGs provide a community-based, interdisciplinary forum for analyses that support and inform planning and prioritization of activities within the Astrophysics Division programs. Operations and structure of the PAGs are described in the Terms of Reference (TOR) which can be found on the three science theme Program Office web pages. The Astrophysics PAGs report their input and findings to NASA through the Astrophysics Subcommittee of the NASA Advisory Council, of which all the PAG Chairs are members. In this presentation, we will provide an overview of the ongoing activities of NASAs Astrophysics PAGs in the context of the opportunities and challenges currently facing the Astrophysics Division. NASA Headquarters representatives for the COPAG, ExoPAG, and PhysPAG will all be present and available to answer questions about the programmatic role of the Astrophysics PAGs.

234.02 – The Cosmic Origins Program Analysis Group (COPAG)

Kenneth Sembach[1]
1. STScI, Baltimore, MD, United States.

The Cosmic Origins Program Analysis Group (COPAG) is tasked by the NASA Advisory Council's Astrophysics Subcommittee to support community coordination and analysis of scientific and technological issues impacting NASA's Cosmic Origins Program. NASA's Cosmic Origins theme encompasses a diversity of astrophysical phenomena ranging from the formation of stars to the development and evolution of the largest assemblages of matter in the universe. The principal tasks of the COPAG in 2013-2014 will be to assess and provide input on technological needs for future space missions, and to form several new study analysis groups with the community on science related to Hubble, JWST, and WFIRST-AFTA. This talk will summarize the status of ongoing analyses and briefly describe these new initiatives, some of which will involve coordination with other Program Analysis Groups.

234.03 – Report from the Exoplanet Exploration Program Analysis Group (ExoPAG)

B. S. Gaudi[1]
1. Ohio State Univ., Columbus, OH, United States.
Contributing teams: The Exoplanet Exploration Program Analysis Group

The Exoplanet Exploration Program Analysis Group (ExoPAG) is responsible for soliciting and coordinating community input into the development and execution of NASA's Exoplanet Exploration Program (ExEP). The ExoPAG serves as a community-based, interdisciplinary forum for analysis in support of activity prioritization and for future exploration. It provides findings of analyses to NASA through the Astrophysics Subcommittee (APS) of the NASA Advisory Council (NAC). The ExoPAG is making an effort to engage a broad cross-section of the exoplanet community, in order to solicit input on ways in which NASA might advance exoplanet research over the next decade. A summary of ExoPAG activities to this end, as well as the recent ExoPAG 8 and 9 meetings, will be given.

234.04 – Summary of PhysPAG Activity

John A. Nousek[1]
1. Penn State Univ., University Park, PA, United States.

The Physics of the Cosmos Program Analysis Group (PhysPAG) is responsible for solicitiing and coordinating community input for the development and execution of NASA's Physics of the Cosmos (PCOS) program. In this session I will report on the activity of the PhysPAG, and solicit community involvement in the process of defining PCOS objectives, planning SMD architecture, and prioritizing PCOS activities. I will also report on the activities of the PhysPAG Executive Committee, which include the chairs of the Science Analysis Groups/ Science Interest Groups which fall under the PhysPAG sphere of interest. Time at the end of the presentation willl be reserved for questions and discussion from the community.

235 – Supernovae & Nebulae II
Oral Session – National Harbor 10 – 07 Jan 2014 02:00 pm to 03:30 pm

235.01D – Searching for Failed Supernovae

Jill Gerke[1], Christopher S. Kochanek[1], Krzysztof Z. Stanek[1]
1. The Ohio State University, Columbus, OH, United States.

Understanding the deaths of massive stars is key to understanding both stellar evolution and the chemical enrichment of the universe. Only by monitoring all the massive stars in a large sample over years are we able to take a statistical approach to the deaths of massive stars and possibly observe the rare phenomenon of a failed supernova, a massive star that collapses to form a black hole without a SN explosion. To this end, we have been monitoring 25 galaxies within 10 Mpc with the Large Binocular Telescope for the past 4 years. Analyzing the data using image subtraction, we monitor the fate of all $\sim 10^6$ evolved supergiants in these galaxies to obtain limits on the rate of failed supernovae. We search for stars that have "vanished'' over the course of our survey, by examining all stars showing a decrease in luminosity of ??L? ? 10^4L™ from the first to the last observation. If we can detect the variable source in our last observation, it is not considered a vanished supergiant or failed supernova. We also identify sources that have increased in luminosity by this same amount, allowing us to estimate our false-positive rates. In addition to the search that does not require a particular signature, we also search for the low luminosity, long period transients predicted by Lovegrove & Woosley (2013) for failed explosions of red supergiants. Among many other applications, the survey also provides photometry of SN progenitors and the first light curves of these stars. Here I present the first results of the survey and provide the first direct limits on the rate of failed supernovae.

235.02 – Supernova flash spectroscopy: a new observational window into stellar death

Avishay Gal-Yam[1]
1. Weizmann Institue of Science, Rehovot, Israel.

We present the technique of flash spectroscopy: rapid spectroscopic observation of supernovae, shortly (hours) after they explode. Strong shock breakout radiation flash-ionizes any surrounding circumstellar material (CSM) distributed around the exploding star, and the resulting recombination emission lines enable a direct measurement of the CSM composition. As the ejecta expand they sweep up the CSM, so a series of spectra tracking the emission line evolution will allow to constrain the physical distribution of gas around each event. The CSM around massive stars is a probe of their evolution during the final year prior to explosion, a critical period not easily accessible till now. We demonstrate the efficacy of this technique with recent studies from the iPTF survey that can regularly detect SNe hours after they explode.

235.03 – Observation of Dust Grain Sputtering in a Shock

John C. Raymond[1], Parviz Ghavamian[2], Brian J. Williams[3], William P. Blair[4], Kazimierz J. Borkowski[5], Terrance J. Gaetz[1], Ravi Sankrit[6]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States. 2. Towson University, Baltimore, MD, United States. 3. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 4. Johns Hopkins University, Baltimore, MD, United States. 5. North Carolina State University, Raleigh, NC, United States. 6. SOFIA Science Center, Mountain View, CA, United States.

We have detected emission in C IV λλ1548,1551 from C atoms sputtered from dust in the gas behind a shock wave in the Cygnus Loop using COS on HST. The intensity agrees approximately with predictions from model calculations that match the Spitzer 24 μm and the X-ray intensity profiles. Thus these observations confirm the overall picture of dust destruction in SNR shocks and the sputtering rates assumed. However, the CIV intensity 10" behind the shock is too high compared to the intensities at the shock and 25" behind it. Projection effects and a complex geometry are probably responsible for the discrepancy.

235.04 – Physical Conditions in Shocked Clouds of the Vela Supernova Remnant: New Results from High-Resolution HST/STIS Observations of HD 72350 and HD 72648

Adam M. Ritchey[1], Edward B. Jenkins[2], George Wallerstein[1]
1. University of Washington, Seattle, WA, United States. 2. Princeton University Observatory, Princeton, NJ, United States.

We present a detailed analysis of the physical conditions in shocked interstellar clouds along two lines of sight through the Vela supernova remnant using new high-resolution HST/STIS spectra of background stars acquired at FUV wavelengths.

From the relative populations of collisionally-excited fine-structure levels in C I and O I, we derive unique solutions for the gas density and kinetic temperature in discrete radial velocity bins along each line of sight. Observations of collisionally-excited Si II provide electron densities, which are used, in conjunction with the previously-derived densities and temperatures, to estimate the strength of the local radiation field from a consideration of the ionization balance between neutral and singly-ionized carbon. Finally, variations in nickel depletion levels allow us to estimate the degree to which dust grains have been destroyed in the highly compressed regions. We discuss the implications of these new results for models of cloud compression and dust grain destruction in supernova shocks.

235.05 – Water, Hydroxyl and Carbon Monoxide Emission in Molecular Supernova Remnants with Herschel

Jeonghee Rho[1], John W. Hewitt[2]
1. SETI Institute and SOFIA Science Center, NASA Ames, Mountain View, CA, United States. 2. NASA/GSFC, Greenbelt, MD, United States.

We present Herschel observations of supernova remnants (SNRs) that are interacting with molecular clouds using PACS, SPIRE and HIFI. Dense clouds behind strong supernova shocks are astrochemical laboratories to study formation or dissociation of various molecules to probe the effect of high energy emission, precursors, or dust processing. Herschel spectra revealed rich molecular lines of high-J and low-J carbon monoxide, water, hydroxyl and a few atomic lines of oxygen and nitrogen. We observed three SNRs and there is some variation in detections SNR by SNR. We will compare shock and pre-existing molecular properties to understand formation of molecules and their interplay of different molecules, present CO excitation diagrams, and distinguish the shock conditions using various shock models. The shock physical conditions will be compared with those derived from molecular hydrogen lines. We will discuss the abundances of CO, water and OH and astrochemical processes of molecules behind dense molecular shocks.

235.06 – Particle Acceleration and Magnetic Fields: Looking at the Northwestern Rim of RCW 86 with Chandra

Daniel Castro[1]
1. MIT, Cambridge, MA, United States.

Non-thermal X-ray emission has been detected from several young shell-type supernova remnants (SNRs), including RX J1713.7-3946, and Vela Jr. These X-rays are believed to be synchrotron radiation from electrons accelerated to TeV energies at the shocks, interacting with the compressed, and possibly amplified, local magnetic field. Observations of gamma-ray emission from several SNRs in the TeV range confirm that particles are being accelerated to energies approaching the knee of the cosmic ray spectrum in these remnants. However, while it is broadly believed that diffusive shock acceleration (DSA) in SNRs produces the bulk of cosmic rays below 1 PeV, we still lack a detailed understanding of the acceleration process and its effects on the the system, such as magnetic field amplification and modifications to hydrodynamic evolution. I will report on our recent observations of the NW rim of SNR RCW 86 with the Chandra X-ray Observatory. This deep look into this SNR allowed us to constrain the magnitude of the post-shock magnetic field in several different regions of the NW rim, where it is significantly amplified relative to the usual ambient fields expected. I will discuss our analysis in detail and comment on how MFA appears to be related to certain characteristics of the SNR shock.

235.07 – The First Fermi-LAT Catalog of Supernova Remnants

Theresa J. Brandt[1], Fabio Acero[2, 1], Jean Ballet[3], Francesco dePalma[4, 5], Francesco Giordano[5], John W. Hewitt[6, 1], Gudlaugur Johannesson[7], Luigi Tibaldo[8]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 2. NASA Postdoctoral Program, Greenbelt, MD, United States. 3. Laboratoire AIM, Service d'Astrophysique, CEA Saclay, Gif sur Yvette, France. 4. Pegaso University, Naples, Italy. 5. INFN, Bari, Italy. 6. CRESST/UMBC, Baltimore, MD, United States. 7. Science Institute, University of Iceland, Reykjavik, Iceland. 8. Kavli Institute for Particle Astrophysics & Cosmology, SLAC National Accelerator Laboratory, Stanford, CA, United States.
Contributing teams: on behalf of the Fermi-LAT Collaboration

The Fermi Gamma-ray Space Telescope has shed new light on many types of galactic objects, including Supernova Remnants (SNRs). With over 15 SNRs identified to date, including 2 with particular evidence for proton acceleration, and over 40 candidates in the 2nd LAT Catalog (2FGL), we are beginning to have sufficient numbers of objects to perform GeV SNR population studies. Moreover, with the wealth of multi-wavelength (MW) data available, we can now characterize in a uniform and consistent manner the GeV emission in all regions containing known SNRs. This permits the first systematic study of SNRs including GeV data, allowing us to classify and study GeV-emitting SNRs. We have also developed a method to explore some systematic effects on SNRs' properties caused by the modeling of the interstellar emission, which is particularly significant for these sources. We will present the results of this study in addition to preliminary SNR Catalog results. We find

an emerging distinction between young SNRs and those, often older, interacting with denser media and indications of a radio-gamma correlation for the latter. In particular, this work provides an ideal context for understanding SNRs interacting with molecular clouds. In combination with MW data, we will constrain emission models of the underlying particle populations, allowing us to quantify both SNR characteristics and SNRs' aggregate contribution to Galactic cosmic rays in a statistically significant manner.

235.08 – GeV constraints of TeV shell SNRs: the case of HESS J1731-347 and SN 1006

Fabio Acero[1,2], Marianne Lemoine-Goumard[3], Matthieu Renaud[4]
1. NASA/Goddard, Greenbelt, MD, United States. 2. ORAU/NPP, Oak Ridge, TN, United States. 3. CENBG, Bordeaux, France. 4. LUPM, Montpellier, France.
Contributing teams: Fermi-LAT collaboration

The current generation of Cherenkov telescopes has revealed in the last decade a dozen supernova remnants (SNRs) radiating in TeV gamma rays. For 5 of those SNRs, the gamma-ray emission is spatially resolved and exhibits a shell-type morphology coincident with the front shock of the SNR. The members of this TeV shell SNR club (RX J1713.7-3946, RX J0852.0-4622, RCW 86, SN 1006 and HESS J1731-347) also share a number of similarities in terms of stage of evolution, surrounding medium, and multi-wavelength properties. In those objects the gamma-ray emission allows us to probe the population of high-energy particles directly at the shock where the acceleration is taking place. Joint studies of the GeV-TeV emission in a multi-wavelength context have proven to be an efficient way to investigate the nature of the gamma-ray emission and to constrain the mechanism of the acceleration and its efficiency. Previous studies have reported Fermi-LAT detections for RX J1713.7-3946 and RX J0852.0-4622 and constraining upper limits for RCW 86. In this study, the Fermi-LAT counterparts of HESS J1731-347 and SN 1006 are investigated with 5 years of P7 reprocessed data using the morphological information derived from the TeV. The multi-wavelength properties of the members of this class are compared and the origin of the gamma-ray emission as well as the efficiency of the acceleration are discussed.

236 – Surveys and Large Programs II

Oral Session – Maryland Ballroom D – 07 Jan 2014 02:00 pm to 03:30 pm

236.01 – The Karl G. Jansky Very Large Array Sky Survey (VLASS)

Steven T. Myers[1], Stefi A. Baum[2], Claire J. Chandler[1]
1. NRAO, Socorro, NM, United States. 2. Rochester Institute of Technology, Rochester, NY, United States.

The Karl G. Jansky Very Large Array is a recently completed rejuvenation of the VLA, providing observers with significantly increased continuum sensitivity and spectral survey speeds (by factors of 100 or more in select cases) from 1-50 GHz and in key bands below 1 GHz. Given the potential for new centimeter-wavelength sky surveys with this enhanced facility, the NRAO VLA Sky Survey (VLASS) has been initiated to explore the science and technical opportunities of a new large survey. A community-led Science Survey Group (SSG) will define the science program and key components of VLASS, and NRAO will support its technical design and implementation. The VLASS could start observing in early 2015, with the data available immediately with no proprietary period and science data products provided to the community in a timely manner. The new VLA can image young stars and massive black holes, measure the strength and topology of the cosmic magnetic field, follow the rapid evolution of energetic phenomena, and study the formation and evolution of stars, galaxies, AGN, and the Universe itself. We can follow the evolution of gas and galaxies and particles and fields to bridge the eras from cosmic dawn to the dawn of new worlds. To address these and other key science challenges requires the VLASS to address a number of key challenges in data management, computation, image processing, and analysis. The development and implementation of capable, efficient, and robust pipeline processing of data, and the production of a basic suite of science data products such as images and catalogs, are all high priorities for VLASS. We will describe the salient capabilities of the Jansky VLA, and highlight complementarity with multi-wavelength multi-messenger sky surveys with other facilities, ultimately leading into the era of the LSST. Exemplary VLA science and commissioning observations will illustrate these features. We will also summarize the outcome of the public NRAO VLASS Science Planning Workshop held on Sunday 5 January 2014 in conjunction with this AAS meeting, and describe the next steps in the VLASS definition process and the opportunities for community involvement in all stages of this project.

236.02 – Exploring the Dynamic Radio Sky

Kunal P. Mooley[1], Steven T. Myers[2], Gregg Hallinan[1], Dale A. Frail[2], Shrinivas R. Kulkarni[1], Assaf Horesh[1], Stephen Bourke[1]
1. California Institute of Technology, Pasadena, CA, United States. 2. National Radio Astronomy Observatory, Socorro, NM, United States.

After the success of the 50 sq. deg Stripe 82 survey for radio transients in 2012, we carried out a wider survey with the Karl G. Jansky Array (VLA) in 2013. We observed 300 sq. deg. at 3 GHz at 3 epochs in Oct-Dec 2013 with 80 uJy rms using, for the first time, the on-the-fly mosaicking technique with VLA. Contemporaneously, we also surveyed the 50 sq. deg. region from 2012 at 8.4 GHz at 3 epochs using the same technique. Uniquely, data calibration, imaging and transient search was completed only a few hours following each observation. This near-real-time processing allowed rapid follow-up (at X-ray through radio frequencies), shedding light on the nature of the detected transients with minimal lag. We have a rich yield of Galactic and extragalactic transients such as magnetically active stars in binaries, renewed jetted activity from quasars, etc. We also have candidate extreme scattering events. In this talk, I will present a subset of these transients and discuss the implications of our 300 sq. deg and 50 sq. deg surveys for future large surveys searching for transients (like the ones with SKA prototypes) and radio counterparts to gravitational wave candidates reported by Advanced-LIGO.

236.03D – All Sky Automated Survey for SuperNovae (ASAS-SN or "Assassin")

Benjamin Shappee[1], Jose Prieto[2], Krzysztof Z. Stanek[1, 6], Christopher S. Kochanek[1, 6], Thomas Holoien[1], Jacob Jencson[1], Udit Basu[1], John F. Beacom[1, 6], Dorota Szczygiel[3], Grzegorz Pojmanski[3], Joseph Brimacombe[5], Matt Dubberley[4], Mark Elphick[4], Steve Foale[4], Eric Hawkins[4], Dave Mullins[4], Wayne Rosing[4], Rachel Ross[4], Zachary Walker[4]
1. The Ohio State University, Columbus, OH, United States. 2. Princeton University, Princeton, NJ, United States. 3. Warsaw University, Warsaw, Poland. 4. Las Cumbres Observatory Global Telescope Network, Santa Barbara, CA, United States. 5. Coral Towers Observatory, Cairns, QLD, Australia. 6. Center for Cosmology and AstroParticle Physics, Columbus, OH, United States.

Even in the modern era, only human eyes scan the entire optical sky for the violent, variable, and transient events that shape our universe. The "All Sky Automated Survey for Supernovae" (ASAS-SN or "Assassin") is changing this by surveying the extragalactic sky roughly once a week, and within a year ASAS-SN will triple in size. We began running our real-time search for variable sources in late April 2013 with our first unit, "Brutus". Brutus presently consists of two telescopes on a common

mount hosted by Las Cumbres Observatory Global Telescope Network in the Faulkes Telescope North enclosure on Mount Haleakala, Hawaii. Each telescope consists of a 14-cm Nikon telephoto lens and has a 4.47 by 4.47 degree field-of-view. On a typical clear night, it can survey 5000+ square degrees. The data are reduced in real-time, and we can search for transient candidates about an hour after the data are taken using an automated difference imaging pipeline. We are now meeting, and frequently exceeding, our current depth goal of V~16 mag, corresponding to the apparent brightness at maximum light of core-collapse SNe within ~30 Mpc and SNe Ia out to ~100 Mpc. Brutus will shortly expand to have four cameras instead of two, and a second unit, "Cassius", with two cameras, should commence operations in early 2014 on Cerro Tololo, Chile. With these expansions, ASAS-SN will be able to observe the entire extragalactic sky every 2-3 nights. ASAS-SN has already discovered 10+ nearby SNe, 100+ outbursts from CVs and novae, 15+ M-dwarf and other stellar flares, and AGN outbursts which have resulted in 35+ ATel and CBET telegrams and 3 publications. In particular, ASAS-SN discovered one of the most extreme M-dwarf Flares ever detected (delta V~9 mag). Furthermore, after triggering on an outburst in NGC 2617 we found that the AGN had changed from a Type 1.8 into a Type 1 Seyfert. After monitoring the transient with Swift and ground-based telescopes for 70 days, we clearly determined that the X-rays drove the variability with the UV-NIR emission showing delays in their response that increased with wavelength. ASAS-SN is an ongoing survey which, judging by its current success and future expansion, promises to be prolific for years to come.

236.04 – The Low Band Observatory (LOBO): A VLA-based Radio LSST for Continuous, sub-GHz Observations in the LSST Era.

Namir E. Kassim[1], Tracy E. Clarke[1], Brian Hicks[1], Joseph F. Helmboldt[1], Wendy M. Peters[1], Thomas L. Wilson[1], Sean Cutchin[3], Scott D. Hyman[5], Frazer N. Owen[2], Richard A. Perley[2], Steven Durand[2], Huib Intema[2], Walter Brisken[2], Joseph Lazio[4]
1. NRL, Washington, DC, United States. 2. NRAO, Socorro, NM, United States. 3. NRL-NRC, Washington, DC, United States. 4. JPL-Caltech, Pasadena, CA, United States. 5. SBC, Sweetbriar, VA, United States.

LOBO is a proposed, dedicated, radio synoptic, high-z spectroscopy, and real-time transient and ionosphere monitoring capability of the Karl G. Jansky VLA. It will make use of the primary focus feeds to observe in parallel with the higher-frequency, Cassegrain feeds. LOBO will have dedicated samplers, fiber transmission, and backend processing systems, the latter to include correlator and pipelined calibration, imaging, and archive systems. With a ? 5 deg^2 field-of-view at meter wavelengths and longer (< 500 MHz), LOBO will perform efficient, blind searches for non-thermal transients and high-redshift spectral lines, e.g. by surveying 64 Mpc^2 at z~4 at 330 MHz in each pointing. LOBO will provide synoptic, wide-field continuum images in a publicly available archive of all targeted VLA fields, annually surveying for ~6000 hours or over 25% of the available sky. We explore the potential for leveraging the scientific potential of this "Radio LSST" capability in the LSST era. A 10-antenna pilot project called the VLA Low Frequency Ionosphere and Transient Experiment (VLITE) is currently funded by NRL and under development with NRAO to explore the LOBO concept.

236.05 – The VLA Low Frequency Sky Survey Redux (VLSSr)

Wendy M. Peters[1], William D. Cotton[2], Namir E. Kassim[1]
1. Naval Research Lab., Washington, DC, United States. 2. National Radio Astronomy Observatory, Charlottesville, VA, United States.

We present the Very Large Array (VLA) Low-frequency Sky Survey Redux (VLSSr), which covers the sky above declinations ? > -30 degrees at a frequency of 74 MHz with 75" resolution and an average RMS noise of 0.1 Jy/beam. The theoretical largest angular size imaged is 36', and there are approximately 95,000 cataloged sources. We have completely re-imaged all data from the original VLSS survey leading to improvements in a number of areas. These include the application of a more accurate primary beam correction which removes substantial radially dependent flux errors present in the VLSS, and smart-windowing to reduce the clean bias by half. We look ahead to the possibility of an expanded, "VLSS generation 2", made by piggybacking observations of the planned VLA Sky Survey (VLASS) using a proposed 24/7 commensal system, called the LOw Band Observatory (LOBO). Catalogs and images for the VLSSr are available at <http://www.cv.nrao.edu/vlss/VLSSlist.shtml>.

236.06D – DES SN Survey Search Strategy: First-Year Results and the Type Ia rate.

John A. Fischer[1]
1. University of Pennsylvania, Philadelphia, PA, United States.
Contributing teams: Dark Energy Survey, DES SN Working Group

The Dark Energy Survey (DES) started its first full season on August 30, 2013. Concurrent with the main survey, the DES SN survey is a next generation photometric SN Survey which is projected to detect approximately 3500 Type Ia supernovae with cosmologically useful light curves from 10 fields (30 square degrees) over its five season observation period. In order to maximize the effectiveness of photometric light curve classification and analysis and to properly characterize these photometric Type Ia SN, we require a certain level of human-data interaction. Using that Extended Science Verification (ESV)

human scanning data, we implemented a SN search strategy which blends a random forest decision tree classifer with a more refined direct human-data interaction to produce viable transients candidates that can then become the focus of additional analysis and potential spectroscopic follow up. A subset of photometrically typed Ia supernovae from ESV and DES Year 1 were then used to calculate a preliminary Type Ia supernova rate, which will also be discussed.

236.07 – The LOFAR Multifrequency Snapshot Sky Survey (MSSS): Status and Results

George Heald[1, 2]

1. ASTRON, Dwingeloo, Netherlands. 2. Kapteyn Astronomical Institute, University of Groningen, Groningen, Netherlands.

Contributing teams: LOFAR collaboration

The Multifrequency Snapshot Sky Survey (MSSS) is the first large-area survey of the northern sky with the Low Frequency Array (LOFAR). By producing images of the sky at 16 frequencies from 30 to 160 MHz, MSSS probes the low-frequency sky at a sensitivity of order 10 mJy/beam, and angular resolution of 1-2 arcmin or better. It thus dramatically expands the frequency range sampled in high-resolution radio surveys, and, crucially, provides low-frequency spectral information about the detected sources. Using LOFAR's unique multi-beaming mode, the survey requires only a rather modest investment in observing time. MSSS began observations in late 2011, and has nearly completed observations in both frequency components (8 frequencies spanning the 30 to 74 MHz range, and another 8 spanning 120 to 160 MHz). MSSS has driven the initial development of the first production version of LOFAR's automatic Imaging Pipeline and spearheaded efforts aimed at solving some of the ongoing low-frequency calibration challenges. In this contribution, I will briefly review the survey design, including an overview of MSSS science topics. I will also present a status update, highlighting early results from the survey such as an in-depth look at the 100 square degree "MSSS Verification Field," new sources discovered in MSSS images, and a sneak peek at the full survey area. I will conclude by describing plans for the future of MSSS, including the possibility of reprocessing the data to obtain enhanced data products such as higher resolution imaging and polarization. LOFAR, the Low Frequency Array designed and constructed by ASTRON, has facilities in several countries, that are owned by various parties (each with their own funding sources), and that are collectively operated by the International LOFAR Telescope (ILT) foundation under a joint scientific policy.

237 – The Cosmic Origins Spectrograph view of the Circumgalactic Medium

Special Session – National Harbor 4 – 07 Jan 2014 02:00 pm to 03:30 pm

Installed in 2009, the Cosmic Origins Spectrograph (COS) is the most sensitive ultraviolet spectrograph yet flown on Hubble. Deep quasar spectra taken with COS contain a wealth of information on foreground absorption systems, which probe the halos of galaxies lying near the line-of-sight. In this Special Session we highlight the progress made by COS in our understanding of the circumgalactic medium (CGM), the interface where galaxies adjoin and interact with intergalactic space. The CGM plays several important roles in galaxy evolution, channeling gas flows into and out of galaxies, harboring substantial reservoirs of metals and baryons, and regulating star formation. COS observations have shown it to be a complex, multi-phase medium with properties that depend on the host galaxy. We will discuss these observations and identify the key remaining CGM questions to be answered in the final years of Hubble's lifetime.

237.01 – The Circumgalactic Medium over Three Decades of Mass: Results from COS-Halos and COS-Dwarfs

Jason Tumlinson[1]
1. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: The COS-Halos Team

I will present the latest results from the combined COS-Halos and COS-Dwarfs programs, which characterize the CGM in HI and metal ines over more than three decades of galactic stellar mass. The CGM as seen by these programs is nearly ubiquitous in HI, patchy in most metals, and generally cool and bound. I will describe the implications of these results for galactic fueling and quenching, and speculate on where we might go from here.

237.02 – The Significant Contribution of Photo-ionized Circumgalactic Gas to the Total Baryonic Budget of L* Galaxies

Jessica Werk[1], Jason X. Prochaska[1], Jason Tumlinson[2], Molly S. Peeples[2], Todd M. Tripp[3], Andrew Fox[2], Nicolas Lehner[4]
1. University of California, Santa Cruz, CA, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. University of Massachusetts, Amherst, MA, United States. 4. Notre Dame, South Bend, IN, United States.
Contributing teams: COS-Halos

If the baryonic content of galaxies consists primarily of stars, interstellar gas, and hot (10^7 K) x-ray halo gas, then galaxies are missing between 70 - 95% of their baryons relative to the cosmological fraction. When accounting for the baryon budget of galaxies, however, we must not overlook the cooler (10^4 K) photo-ionized gas phase that makes up the circumgalactic medium (CGM). Our collaboration, COS-Halos, has been working to characterize the elusive multiphase CGM that extends out to at least 300 kpc from stellar components of galaxies. Specifically, we have observed the halo gas of 50 galaxies drawn from the imaging dataset of the Sloan Digital Sky Survey (SDSS) whose angular offsets from quasar sight-lines and redshifts imply impact parameters (? < 150 kpc) well inside their virial radii. As we have shown in previous empirical studies, these data comprise a carefully-selected statistically-sampled map of the physical state and metallicity of the CGM for L ? L* galaxies. Of particular relevance to the halo missing baryon problem is the total baryonic mass contained in the multiphase CGM, as traced by absorption from hydrogen and metal lines in various ionization states (e.g. MgII, SiII, CII, SiIII, CIII, SiIV, OVI). In this talk, I will describe how I have modeled the photo-ionized gas of the CGM with a range of physical conditions, and rigorously determined the CGM gas ionization parameters and metallicities along 33 of the COS-Halos sight-lines that provide the best-determined measurements of HI and metal-line column densities. With the constraints imposed by the data and models, I am able to provide the most reliable mass estimate of the CGM to date, and show definitively that the CGM is an important reservoir of baryons on galactic scales.

237.03 – Large Reservoirs Of Metal-Poor Gas Around z<1 Galaxies

Nicolas Lehner[1], J. C. Howk[1], Christopher Wotta[1], Jason Tumlinson[2], Todd M. Tripp[3], Jason X. Prochaska[4], John O'Meara[5], Jessica Werk[4], Andrew Fox[2], Joseph Ribaudo[6]
1. Univ. Of Notre Dame, Notre Dame, IN, United States. 2. STScI, Baltimore, MD, United States. 3. UMass, Amherst, MA, United States. 4. UCO/Lick Observatory, SANTA CRUZ, CA, United States. 5. St Michael College, Colchester, VT, United States. 6. Utica College, Utica, NY, United States.

Large-scale outflows and inflows through the circumgalactic medium (CGM) strongly affect the shape, structure, and evolution of galaxies. The metallicity distribution of gas in the CGM can shed light on the balance of infalling and outflowing material about galaxies. Using Hubble COS and ground-based observations, we have determined the metallicity distribution function of the cool CGM at z<1. It is strongly bimodal with metal-poor and metal-rich branches peaking at about 3% and

237.04 – The Signatures of Star formation on the Properties of the Circumgalactic Medium

Sanchayeeta Borthakur[1]
1. Johns Hopkins University, Baltimore, MD, United States.

The circumgalactic medium (CGM) is the interphase through which matter and energy flow in and out of a galaxy. In this talk, I will show how the CGM can be influenced by strong burst of star formation and in turn can provide some insight on the regulatory mechanism underlying the process of star formation. I will also comment on the presence of cold gas around galaxies and how the global properties of galaxies connected to that of its CGM.

237.05 – Characterizing the Circumgalactic Medium of Nearby Galaxies

Brian A. Keeney[1], John T. Stocke[1], Charles Danforth[1], Blair D. Savage[2], Cynthia S. Froning[1, 3], James C. Green[1]
1. Univ. of Colorado, Boulder, CO, United States. 2. Univ. of Wisconsin, Madison, WI, United States. 3. Univ. of Texas, Austin, TX, United States.

We have detected and characterized the circumgalactic medium (CGM) of nearby late-type galaxies using both targeted and serendipitous QSO/galaxy pairs at $z < 0.2$. Photoionization modeling of warm CGM clouds finds volume filling factors of ~5%, cloud sizes of 0.1-30 kpc, cloud masses of $10\text{-}10^8$ $M_™$, and metallicities of ~0.1-1 $Z_™$. The total mass of these warm clouds surrounding $L > 0.1$ $L*$ galaxies approaches 10^{10} $M_™$, comparable to the total baryons in massive galaxy disks. We also find evidence for an extensive (>500 kpc), hot (10^5 - 10^6 K) intracloud medium that is very massive (> 10^{11} $M_™$). We interpret this hot, massive baryon reservoir as the intragroup medium of spiral-rich galaxy groups and find that its inclusion can solve the missing baryon problem in spiral galaxies.

237.06 – Bridging the Observational Gaps: Milestones toward Understanding the Circumgalactic Medium

Christopher W. Churchill[1]
1. New Mexico State Univ., Las Cruces, NM, United States.

It is broadly recognized that the gaseous circumgalactic medium (CGM) is a key component of galaxies and that the CGM is the conduit between the interstellar medium and the intergalactic medium and that it holds a prominent role in governing the large scale physics of galaxy formation and evolution. The COS spectrograph is the primary vital facility for measuring the wide range of multi-phase gas properties of the CGM at intermediate redshifts. But, in the context of absorption line studies, what is really required, observationally and theoretically, if we are to develop a broader perspective of the physical processes in the CGM and how these processes relate to the cause and effect cycles of gas that regulate galaxy evolution and give rise to the global observed distribution of galaxies in the universe? In this contribution, we will briefly outline the observables and theoretical paradigm that need to be brought together to strongly advance our understanding of the CGM.

238 – The Galactic Center
Oral Session – Potomac Ballroom C – 07 Jan 2014 02:00 pm to 03:30 pm

238.01 – Extreme Gas Properties in the Central 10 Parsecs

Elisabeth A. Mills[2, 1], Rolf Güsten[4], Miguel A. Requena Torres[4], Cornelia C. Lang[3], Mark Morris[1], Natalie Butterfield[3], Dominic Ludovici[3], Susan Schmitz[3], Juergen Ott[2]
1. UCLA, Santa Monica, CA, United States. 2. NRAO, Socorro, NM, United States. 3. U. Iowa, Iowa City, IA, United States. 4. MPIfR, Bonn, Germany.

Gas in the central parsecs of our Galaxy is subject to a harsh environment, including the close proximity of a supermassive black hole and a massive nuclear star cluster. By characterizing the molecular gas conditions in this region, it is possible not only to quantify the effect the black hole and star cluster have on nearby gas, we can also help to infer the future evolution of the central parsec by determining whether this gas will form stars, accrete, or escape entirely. We present a combination of results from the APEX, VLA, and GBT telescopes which place new limits on the large densities, temperatures, and turbulent line widths found in the molecular gas in the Circumnuclear disk (CND) and the central 10 parsecs. Using data from the APEX telescope, we find that the majority of gas in the CND is not stable against tidal disruption, and all but one clump studied are likely transient. We additionally find that reprocessed dust radiation from the central cluster appears to be contributing to radiative excitation of HCN in the CND, which may lower the gas densities inferred using this molecule. We also use VLA and GBT data to identify a new 400 K gas component in several clouds in the central 10 parsecs, and evaluate the supermassive black hole and central star cluster as potential heating sources for this gas. Finally, we will present a new study of the distribution of gas temperatures and turbulence in the central 10 parsecs, and a search for trends in these properties as a function of distance from the nucleus. Together, these studies place new constraints on the most extreme conditions found in Galactic center molecular gas, and the processes which are responsible.

238.02D – Plasma evolution around Sgr A*

Salome Dibi[1], Sera Markoff[1], Renaud Belmont[2], Julien Malzac[2], Nicolas Barriere[3], John Tomsick[3]
1. Anton Pannekoek Institute, Amsterdam, Amsterdam, Netherlands. 2. IRAP, Toulouse, France. 3. SSL, Berkeley, CA, United States.

We present a new way of describing the flares occurring in the Galactic Center. We model Sgr A* within a single zone with a self-consistent calculation of the particle distribution. All the relevant radiative processes are taken into account in the evolution of the electron distribution and in the resulting spectrum. We explore the multi-wavelength quiescent and flaring spectra from Sgr A*. We present some spectral modelling for the new X-ray data flares observed by NuSTAR in July 2012, together with older observations in different wavelengths, and we discuss the physical parameters that need to be modified in the plasma in order to produce a flare. The results allow us to give an interpretation to the flaring events generated very close to the central super-massive black hole without assuming a given particle distribution. We conclude that the flare data (including the new X-ray flare) are more likely generated by a weakly magnetized plasma in which particles can be injected and escape. Such a plasma, with prescription for non-thermal acceleration, injection, escape and cooling losses, gives a spectrum with a break between the infra-red and the X-ray, allowing a better simultaneous match in the different wavelengths. Even-though inverse Compton emission for the X-ray flare is not excluded, the parameters favour the non-thermal synchrotron spectrum. We also consider a modification of Sgr A* quiescent spectrum with an increase of the plasma density in order to give an observable prediction of what is likely to be happening when the cloud G2 falls into the Galactic Centre this year.

238.03 – Sensitive X-ray and Radio Monitoring of the Sgr A*/G2 Encounter

Daryl Haggard[1], Frederick K. Baganoff[2], Gabriele Ponti[6], Craig O. Heinke[5], Farhad Yusef-Zadeh[1], Douglas A. Roberts[1], William D. Cotton[8], Stefan Gillessen[6], Reinhard Genzel[6], Sera Markoff[4], Michael Nowak[2], Joseph Neilsen[3], Norbert S. Schulz[2], Nanda Rea[7]
1. Northwestern University/CIERA, Evanston, IL, United States. 2. MIT/Kavli, Boston, MA, United States. 3. Boston University, Boston, MA, United States. 4. University of Amsterdam, Amsterdam, Netherlands. 5. University of Alberta, Alberta, AB, Canada. 6. Max-Planck-Institut für extraterrestrische Physik, Munich, Germany. 7. Institute of Space Sciences, CSIC-IEEC, Barcelona, Spain. 8. NRAO, Charlottesville, VA, United States.

The recent discovery of a dense, cold cloud (dubbed "G2") approaching Sgr A* offers an opportunity to test models of black hole accretion and its associated feedback. G2's orbit is eccentric and the cloud shows signs of tidal disruption by the black hole. High-energy emission from the Sgr A*/G2 encounter may rise toward pericenter (mid-to-late 2013, or early 2014) and continue over the next several years as the material circularizes. This encounter is also likely to enhance Sgr A*'s flare activity across the electromagnetic spectrum. We present preliminary results from our 2013 joint Chandra/XMM/VLA

monitoring campaigns. Our programs aim to study the radiation properties of Sgr A* as G2 breaks up and feeds the accretion flow, to constrain the rates and emission mechanisms of faint X-ray flares, and to detect G2 itself as it is shocked and heated. We discuss the constraints these data place on theoretical models for the Sgr A*/G2 encounter and outline plans for continued monitoring with Chandra, XMM, HST, and VLA in 2014.

238.04 – NIR variability of Sgr A*

Gunther Witzel[1]
1. UCLA, Los Angeles, CA, United States.

We discuss recent synchronous observations of Sgr A* with NIRC2@KECKII and OSIRIS@KECKI in L'-band and H-band, respectively. These observations represent the first truly synchronous high cadence dataset to test for time variability of the spectral index within the near infrared. In our measurement of unprecedented precision we found a constant spectral index between both bands. Furthermore, these high cadence data show effects on time scales as short as 20 seconds. We discuss the significance of both findings in the frame work a rigorous statistical model of the variability and explore possible physical explanations.

238.05 – Is G2 Alone? Other Infrared Sources in the Central 0.04 Parsecs of the Galactic Center

Breann Sitarski[1], Tuan Do[2], Gunther Witzel[1], Andrea M. Ghez[1], Leo Meyer[1], Anna Boehle[1], Jessica R. Lu[3], Sylvana Yelda[1], Mark Morris[1], Eric E. Becklin[1, 4]
1. UCLA, Los Angeles, CA, United States. 2. Dunlap Institute for Astronomy and Astrophysics, University of Toronto, Toronto, ON, Canada. 3. Institute for Astronomy, University of Hawaii, Honolulu, HI, United States. 4. NASA-Ames Research Center, Moffet Field, CA, United States.

G2 has recently been subject to intense scrutiny as a potential gas cloud that may reach closest approach to Sgr A* within the next year. It appears to be a very red source and is only detected at L' and in Br-? emission. Using imaging and integral field spectroscopy with laser guide star adaptive optics on the Keck I and II telescopes, we report our detections and kinematics of other faint, red emission-line objects found in the central arcsecond of the Galactic Center. Studying these other objects will allow us to determine whether they are similar in nature to G2 or differ drastically.

238.06 – A CARMA Spectral Line and Continuum Survey of the Central Molecular Zone

Marc W. Pound[1], Farhad Yusef-Zadeh[2]
1. Univ. of Maryland, College Park, MD, United States. 2. Northwestern University, Evanston, IL, United States.

Because of its large angular extent, the Central Molecular Zone has to date only been mapped at millimeter wavelengths with singledish telescopes, with resolution about 1.2 pc (30"). We have completed a 3 mm continuum and spectral line interferometric maps made with CARMA of a 90 pc X 50 pc region of the CMZ (0.6 < l < -0.2; 0.15 < b < -0.2), with resolution of ~0.3 pc We present here the first results of this survey. One of the advantages of observing the Galactic Center at 3mm with CARMA iis that it allows identification of different classes of objects in this confusing region of the Galaxy. This is the first 3mm continuum survey showing a high concentration of HII complexes, and thermal and nonthermal sources distributed throughout the region. Our continuum survey identifies a number of infrared dark clouds, the most prominent of which is G0.253+0.016, part of a chain of clouds forming a ridge of molecular gas between G0.253+0.016 and Sgr B2. We also see emission from the magnetized filaments in the l = 0.2 Radio Arc. We combined our spectral line maps of SiO(2-1), HCO+(1-0), HCN(1-0), N2H+(1-0) with the MOPRA singledish survey so the final maps include all spatial frequencies down to 3". The combined CARMA plus MOPRA maps show a rich structure of both compact and filamentary clouds. We examine the relationship between the distribution of molecular line emission, the 6.4 keV Fe K-alpha emission, and the nonthermal radio emission and discuss preliminary results of the analysis.

238.07 – Multi-epoch Measurements of the Galactic Center (~6667 MHz) and the Blazar 0716+714 (1 & 3 MHz) taken from the Allen Telescope Array at Hat Creek Radio Observatory in 2013

Aaron Castellanos[1, 2], Gerald Harp[2, 3]
1. California State Polytechnic University, Pomona, CA, United States. 2. SETI Institute, Mountain View, CA, CA, United States. 3. Institute of Electrical and Electronic Engineers (IEEE), Mountain View, CA, CA, United States.

The Allen Telescope Array (ATA) is a 42 radio dish array located in Hat Creek, CA and is used to search for traces of

Extraterrestrial Intelligence (SETI) and to study the interstellar medium. The ATA has taken multi-epoch measurements of the Galactic Center (~6667 MHz) and the intraday variable Blazar 0716+714 (1 & 3MHz) and are imaged on 10 second timescales to search for intensity fluctuations on timescales 10s and beyond. We utilize software developed and focused on antenna system temperatures to minimize Radio Frequency Interference (RFI) in order to enhance calibration and signal variability. We will discuss potential radio bursts from the Galactic Center, possibly originating from the descent of the gas cloud G2 into the Galactic Center.

259 – HAD VII: Oral History Project
Oral Session – National Harbor 3 – 07 Jan 2014 02:00 pm to 02:15 pm

259.01 – HAD Oral History Project

Jarita Holbrook[1]
1. University of the Western Cape, Bellville, Western Cape, South Africa.

The Historical Astronomy Division is the recipient of an American Institute of Physics Neils Bohr Library Grant for Oral History. HAD has assembled a team of volunteers to conduct oral history interviews since May 2013. Each oral history interview varies in length between two and six hours. This presentation is an introduction to the HAD Oral History Project and the activities of the team during the first six months of the grant.

239 – Heineman Prize: The Formation of Galaxies and Supermassive Black Holes: Insights and Puzzles

Plenary Session – Potomac Ballroom A – 07 Jan 2014 03:40 pm to 04:30 pm

239.01 – The Formation of Galaxies and Supermassive Black Holes: Insights and Puzzles

Rachel S. Somerville[1]

1. Rutgers University, Piscataway, NJ, United States.

Galaxies exist at a nexus of physical scales, molded by physics ranging from the "small" scales of star formation and accretion onto nuclear black holes, up to the very large scales of the cosmic web. It is this special property that makes galaxies so fascinating and so challenging to study, both observationally and theoretically. The past two decades have seen enormous progress in our understanding of how galaxies form and evolve. We have surveyed slices of the sky at many wavelengths, and built sophisticated models and simulations that attempt to capture the complex array of physics that influences galaxy evolution. We are only now coming into possession of large samples of galaxies for which we can study the internal structure as well as the large scale environment in detail, from the epoch of 'cosmic high noon' (z~2) to the present. At the same time, numerical simulations set within a cosmological framework have only recently succeeded in building galaxies with realistic internal structures. It has been known for several years that galaxies are growing in mass and radius, experiencing morphological transformation, and 'downsizing' their star formation activity over cosmic time. Now, new observations are painting a picture in which the internal structure of galaxies (size and morphology) is intimately linked with their star formation activity and formation history. There are hints that the co-evolution of supermassive black holes with their host galaxies may be the driving force behind these correlations – but this remains controversial. While cosmological simulations set within the hierarchical formation scenario of Cold Dark Matter currently offer a plausible story for interpreting these observations, many puzzles remain. I will review recent insights gleaned from deep multi-wavelength surveys and state-of-the-art theoretical models and simulations, as well as highlight the open questions and challenges for the future.

240 – HEAD Rossi Prize: The Amazing Pulsar Machine, Alice K. Harding and The Pulsing Gamma-ray Sky, Roger Romani

Plenary Session – Potomac Ballroom A – 07 Jan 2014 04:30 pm to 05:20 pm

240.01 – The Amazing Pulsar Machine

Alice K. Harding[1]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States.
Contributing teams: Fermi Large Area Telescope

How rotation-powered pulsars accelerate particles to PeV energies and radiate pulsed emission from radio to gamma-ray wavelengths has remained a mystery for over 40 years. But in the last few years, the Fermi Large Area Telescope has revolutionized the study of pulsars and allowed us to peer deeper into the inner workings of this incredibly efficient natural accelerator. Thanks to Fermi discoveries, we now know that the high-energy emission is radiated in the outer magnetosphere, near the light cylinder, that millisecond pulsars are extremely efficient at emitting gamma-ray pulses and that the Crab nebula undergoes dramatic flaring that challenges particle acceleration theory. I will review how these discoveries, together with recent progress in global simulation of pulsar magnetospheres, are changing our models of pulsar particle acceleration, cascade pair production and high-energy emission.

240.02 – The Pulsing Gamma-ray Sky

Roger W. Romani[1,2]
1. Dept. of Physics, Stanford University, CA, United States. 2. KIPAC, Stanford University, CA, United States.

The Fermi Space Telescope, with its discovery of nearly 150 gamma-ray pulsars has solidified and extended the suspicions of the EGRET era: energetic spin-powered pulsars are fantastic particle accelerators, they emit most of their photon energy in the GeV range and they paint their gamma-ray beams over much of the sky. I summarize here the suite of gamma-ray discoveries and what it has taught us about pulsar populations. Young, classical radio-detectable pulsars, gamma-ray only `Gemingas' and energetic millisecond pulsars are equally represented in the Fermi sky. This sample certainly reveals much about magnetospheric physics. However, by chasing down the pulsars responsible for Fermi sources we continue to discover exotic systems whose study impacts a wide range of high energy astrophysics. Gamma-ray pulsars are revealing details of close binary evolution, testing the equation of state of ultra-dense matter, helping us understand the cosmic ray positrons, and aiding in the search for ultra-low frequency gravitational radiation. I summarize recent progress on these fronts and the prospects for more exciting discoveries to come.

241 – HEAD Business Meeting

Town Hall – National Harbor 2 – 07 Jan 2014 06:30 pm to 07:30 pm

The annual meeting of the HEAD Division, known in the HEAD bylaws as the "Regular Meeting." Open to all HEAD members, the meeting will include a Business Session devoted exclusively to the reports of officers and committees, and to the transaction of business affairs. In particular, the results of the upcoming HEAD elections of a new Vice Chair and two new Executive Committee members will be announced, and there will be time for discussion of the proposed new bylaws that would allow for a new class of 'Affiliate' HEAD members.

242 – National Radio Astronomy Observatory Town Hall

Town Hall – Potomac Ballroom C – 07 Jan 2014 06:30 pm to 08:30 pm

This Town Hall will inform the AAS membership about the status of National Radio Astronomy Observatory (NRAO) science and science operations, development programs, and construction projects. This Town Hall will open with a reception that will be followed by a presentation by NRAO Director Tony Beasley that will update the membership regarding: (a) Construction progress at the Atacama Large Millimeter/submillimeter Array (ALMA); (b) Science opportunities and development programs at ALMA, the Jansky Very Large Array (VLA), the Green Bank Telescope (GBT), and the Very Long Baseline Array (VLBA); (c) Recent science results from across NRAO; and (d) Technical development for the next generation of radio astronomy research facilities. The NRAO Town Hall will include at least 30 minutes for answering audience questions.

300 – Pierce Prize: Exploring the Stellar Graveyard of the Milky Way

Plenary Session – Potomac Ballroom A – 08 Jan 2014 08:30 am to 09:20 am

300.01 – Exploring the Stellar Graveyard of the Milky Way

Jason S. Kalirai[1, 2]

1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Johns Hopkins University, Center for Astrophysical Sciences, Baltimore, MD, United States.

98% of all stars will end their lives as white dwarfs. In old stellar populations, such as globular clusters and stellar halos, the bulk of the progenitor stellar mass function above the present day turnoff is therefore now populated on the white dwarf cooling sequence. These remnants have remarkable properties and can be studied in exquisite detail to reveal their temperatures, gravities, and masses. In this talk, I will describe unprecedented recent HST imaging and Keck spectroscopic observations of these stars in old stellar populations. This work has led to three new discoveries, 1.) The first global constraints on the mapping between initial stellar mass and final mass, and therefore new insights on stellar evolution theory, mass loss, and chemical enrichment of the interstellar medium. 2.) A new technique to invert the process of stellar evolution to establish a relation between the remnant mass in an old stellar population and the parent age. Application of this technique to nearby Milky Way halo stars leads to a sensitive and independent measure of the age of the inner halo of the Milky Way. 3.) Metallicity-independent and sub-Gyr age measurements for Milky Way globular clusters using their full white dwarf cooling sequences.

343 – Time Domain Astronomy, the Large Synoptic Survey Telescope, and Transient Follow-up Poster Session

Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

343.01 – Variable target discovery rates in the LSST survey

Stephen T. Ridgway[1], Thomas Matheson[1], Kenneth J. Mighell[1], Knut A. Olsen[1], Steve B. Howell[2]
1. NOAO, Tucson, AZ, United States. 2. NASA Ames Research Center, Moffett Field, CA, United States.

Collected data for stars, galaxies, asteroids and SNe are used to predict the LSST discovery rate for variable targets. The rates begin very high, but with successful identifications, the discovery rates can decline rapidly over 1-2 years. This front-loading of discoveries of the most numerous types will facilitate the study of those targets, and will simplify the discovery of less common variables.

343.02 – ANTARES: A Prototype Transient Broker System

Thomas Matheson[1], Abhijit Saha[1], Richard Snodgrass[2], John Kececioglu[2]
1. NOAO, Tucson, AZ, United States. 2. University of Arizona, Department of Computer Science, Tucson, AZ, United States.

The Arizona-NOAO Temporal Analysis and Response to Events System (ANTARES) is a joint project of the National Optical Astronomy Observatory and the Department of Computer Science at the University of Arizona. The goal is to build the software infrastructure necessary to process and filter alerts produced by time-domain surveys, with the ultimate source of such alerts being the Large Synoptic Survey Telescope (LSST). ANTARES will add value to alerts by annotating them with information from external sources such as previous surveys from across the electromagnetic spectrum. In addition, the temporal history of annotated alerts will provide further annotation for analysis. These alerts will go through a cascade of filters to select interesting candidates. For the prototype, 'interesting' is defined as the rarest or most unusual alert, but future systems will accommodate multiple filtering goals. The system is designed to be flexible, allowing users to access the stream at multiple points throughout the process, and to insert custom filters where necessary. We will describe the basic architecture of ANTARES and the principles that will guide development and implementation.

343.03 – LSST Capability for Transiting Exoplanet Detections

Michael Lund[1], Joshua Pepper[3, 1], Keivan Stassun[1, 2]
1. Vanderbilt University, Nashville, TN, United States. 2. Fisk University, Nashville, TN, United States. 3. Lehigh University, Bethlehem, PA, United States.

Over its decade-long run, the Large Scale Synoptic Survey (LSST) will gather several hundred multi-band photometric observations of approximately ten billion stars. While not its primary purpose, this represents in principle the same methodology that has been used by numerous surveys to discover over two hundred transiting extrasolar planets to date. While these surveys have used much higher cadences to make those discoveries, LSST will have some advantages for discovery. It will observe far more stars than any transit surveys to date, it will include data in multiple filters, and will probe populations that have not been previously surveyed for planets. The LSST deep drilling fields are of specific interest given their higher observing rate. We investigate the types and numbers of transiting planets that could be potentially extracted from the LSST dataset, as well as what expected constraints we can place on the population of planets.

343.04 – Multidimensional Quasar Classification for Next Generation Surveys

Christina M. Peters[1], Gordon T. Richards[1]
1. Drexel University, Philadelphia, PA, United States.

We used the Non-parametric Bayesian Classification Kernel Density Estimation (NBC KDE) quasar selection algorithm to classify data sets of spectroscopically confirmed quasars and non-quasars in Sloan Digital Sky Survey (SDSS) Stripe 82 and demonstrate the effectiveness of selection using the combination of color, time domain, and astrometric information. Eight values were calculated to use for classification: four colors (u-g, g-r, r-i, and i-z), two parameters calculated from fitting the structure function of the object with a power law model that describes the variability of the object, and two parameters that describe the positional offsets caused by differential chromatic refraction (DCR) that give information about spectral features of the object. In the parameter space of each of these methods there are distinct regions for quasars and non-quasars, but also regions where they overlap. Using both variability and astrometry in combination with colors we are able to increase the purity of quasar selection over colors alone, and combining variability, astrometry, and colors together increases the purity further. In particular, there is an improvement in the selection of quasars of redshift 2.7 to 3.5 where quasars and stars have similar colors.

343.05 – Towards Precision Quasar Light Curve Photometry with the Pan-STARRS1 Survey

Tingting Liu[1], Suvi Gezari[1]
1. University of Maryland, College Park, MD, United States.
Contributing teams: The Pan-STARRS1 Science Collaboration

We demonstrate the application of the precision photometry technique of inhomogeneous ensemble photometry on the Pan-STARRS1 (PS1) Small Area Survey (SAS), with the motivation of constructing high quality light curves of variable quasars. The PS1 SAS is a test area of ~70 deg^2 that was observed in 2011 to the final depth of the PS1 3? survey, an all-sky five-band optical survey above -30 deg declination to be completed in 2014. We follow the methodology of Bhatti et al. (2010), who adapted the technique described in Honeycutt (1992) to the SDSS Stripe 82 survey. By comparing a target object with nearby non-variable stars on a given image, systematic errors due to exposure-to-exposure variations in atmospheric conditions are greatly reduced, thereby providing a powerful tool for variability studies. Our ultimate goal is to obtain a large sample of such precisely measured multi-epoch light curves of quasars in PS1, and to study their variability in a statistical sense in comparison with theoretical predictions. We conclude with the exciting capabilities of similar studies done using future large surveys such as the Large Synoptic Survey Telescope (LSST).

343.06 – Photometric and Astrometric Characterization of the La Silla QUEST AGN Variability Survey

Paolo S. Coppi[1], Regis A. Cartier[2]
1. Yale Univ., New Haven, CT, United States. 2. University of Chile, Santiago, Chile.
Contributing teams: The QUEST Team

We study the photometric and astrometric properties of the La Silla QUEST AGN Variability Survey and present preliminary results. This wide-field survey is designed to collect well-sampled AGN light curves, on day to year timescales, in order to better characterize the variability properties of a large sample of AGN selected by a variety of other techniques. These properties can then be used to test and improve AGN variability selection techniques, e.g., to better prepare for the arrival of LSST. Additionally, we hope to connect these variability properties to the fundamental physical parameters of AGN such as black hole mass. To achieve this goal, we carry out nightly observations of a set of extragalactic fields with good multiwavelength coverage such as COSMOS. The survey uses the QUEST camera (with ~7.5 square degree field-of-view) operating on the 1m ESO Schmidt located in La Silla, Chile. The survey began in March 2010 and will likely continue for at least two more years. We review our progress and present sample AGN light curves from the first two years of the survey. We use the two-year data to test for possible biases in current selection variability techniques by looking at the known AGN in the COSMOS field. The larger QUEST variabiliity survey, which is now being used to find supernova, will eventually provide high-quality AGN variability data over ~15,000 square degrees of sky.

343.07 – Improving the LSST Observing Cadence for Type Ia Supernovae

Christopher M. Carroll[1,2], Eric J. Gawiser[1], Saurabh Jha[1], Peter Kurczynski[1], Rahul Biswas[4], David Cinabro[5], R. L. Jones[3], W. M. Wood-Vasey[6]
1. Dartmouth College, Hanover, NH, United States. 2. Rutgers University, New Brunswick, NJ, United States. 3. University of Washington, Seattle, WA, United States. 4. Argonne National Laboratory, Lemont, IL, United States. 5. Wayne State University, Detroit, MI, United States. 6. University of Pittsburgh, Pittsburgh, PA, United States.

The Large Synoptic Survey Telescope (LSST) will undertake a revolutionary exploration of the astronomical time domain. The LSST design is advanced but leaves significant freedom in the cadence of when a given field on the sky will be observed in each filter. We show that the nominal observing cadence will provide light curves of sufficient quality for cosmology for ~5,000 Type Ia supernovae in the main survey, with another ~10,000 expected in the Deep Drilling Fields. Significant improvements in supernova statistics can be realized by concentrating observations of each field more closely in time. We therefore propose an observing strategy where LSST concentrates on one-third of its main survey area each year; this would enable a factor ~10 increase in the number of main survey Type Ia supernovae useful for cosmology.

343.08 – Optimizing the LSST Dither Pattern for Dark Energy Studies

Eric J. Gawiser[1], Christopher M. Carroll[2,1], Peter Kurczynski[1], R. L. Jones[3], Aneesa Sonawalla[4,1], Rachel Bailey[1], K. S. Krughoff[3]
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IL, United States.

The Large Synoptic Survey Telescope (LSST) will discover billions of distant galaxies in deep co-added ugrizy images over its ten-year survey. These unprecedented data will be used to determine the nature of dark energy and to distinguish it from modifications to general relativity. To take full advantage of the unprecedented statistics requires minimizing systematic errors, including those caused by non-uniformity in the co-added survey depth. Spurious power on the scale of the 3.5 degree diameter LSST field-of-view is a particular concern, as this equals the Baryon Acoustic Oscillation (BAO) scale at z=1. We show that large dithers of amplitude close to the radius of the LSST field-of-view are required to avoid significant artificial structure that would be impossible to correct fully and would therefore harm large-scale structure (BAO), galaxy cluster, and weak gravitational lensing analyses. However, large dithers are undesirable for the LSST Deep Drilling Fields, so we propose an "optimal" strategy that utilizes large dithers for the main survey and minimal dithers for the Deep Drilling Fields.

344 – Preparing for Future NASA Missions Poster Session

Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

344.01 – Overview and Summary of the Advanced Mirror Technology Development Project

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Advanced Mirror Technology Development (AMTD) is a NASA Strategic Astrophysics Technology project to mature to TRL-6 the critical technologies needed to produce 4-m or larger flight-qualified UVOIR mirrors by 2018 so that a viable mission can be considered by the 2020 Decadal Review. The developed mirror technology must enable missions capable of both general astrophysics & ultra-high contrast observations of exoplanets. Just as JWST's architecture was driven by launch vehicle, a future UVOIR mission's architectures (monolithic, segmented or interferometric) will depend on capacities of future launch vehicles (and budget). Since we cannot predict the future, we must prepare for all potential futures. Therefore, to provide the science community with options, we are pursuing multiple technology paths. AMTD uses a science-driven systems engineering approach. We derived engineering specifications for potential future monolithic or segmented space telescopes based on science needs and implement constraints. And we are maturing six inter-linked critical technologies to enable potential future large aperture UVOIR space telescope: 1) Large-Aperture, Low Areal Density, High Stiffness Mirrors, 2) Support Systems, 3) Mid/High Spatial Frequency Figure Error, 4) Segment Edges, 5) Segment-to-Segment Gap Phasing, and 6) Integrated Model Validation Science Advisory Team and a Systems Engineering Team. We are maturing all six technologies simultaneously because all are required to make a primary mirror assembly (PMA); and, it is the PMA's on-orbit performance which determines science return. PMA stiffness depends on substrate and support stiffness. Ability to cost-effectively eliminate mid/high spatial figure errors and polishing edges depends on substrate stiffness. On-orbit thermal and mechanical performance depends on substrate stiffness, the coefficient of thermal expansion (CTE) and thermal mass. And, segment-to-segment phasing depends on substrate & structure stiffness. This presentation will introduce the goals and objectives of the AMTD project and summarize its recent accomplishments.

344.02 – Protective coatings for FUV to NIR advanced telescope mirrors

Kunjithapatham Balasubramanian[1], Shouleh Nikzad[1], John Hennessy[2], Nasrat Raouf[1], James C. Green[4], Paul A. Scowen[3]

1. Jet Propulsion Laboratory, Pasadena, CA, United States. 2. California Institute of Technology, Pasadena, CA, United States. 3. Arizona State University, Tempe, AZ, United States. 4. University of Colorado, Boulder, CO, United States.

The NASA Cosmic Origins Program Annual Technology Report of Oct 2011 defined the goal for the "Development of UV coatings with high reflectivity (>90-95%), high uniformity (<1-0.1%), and wide bandpasses (~100 nm to 300-1000 nm)". We address this goal by exploring applicable materials and processes to produce protected aluminum mirror coatings that will satisfy the needs of future space telescope systems of interest to NASA and the astrophysics community. Void-free thin films of absorption-free materials are required to protect and maintain high reflectivity and durability of aluminum mirrors in laboratory and pre-launch environments. Precisely controllable and scalable deposition process is also required to produce such coatings on large telescope mirrors. In this report, we present our preliminary experimental studies on various fluoride coatings by conventional coating techniques. MgF_2 coating by Atomic Layer Deposition (ALD), a promising technique, is also presented. Spectrophotometric and ellipsometric measurements of the optical properties of these coatings are reported.

344.03 – MEMS Deformable Mirror Technology Development for Space-Based Exoplanet Detection

Paul Bierden[1], Steven Cornelissen[1], Peter Ryan[1]

1. Boston Micromachines Corp., cambridge, MA, United States.

In the search for earth-like extrasolar planets that has become an important objective for NASA, a critical technology development requirement is to advance deformable mirror (DM) technology. High-actuator-count DMs are critical components for nearly all proposed coronagraph instrument concepts. The science case for exoplanet imaging is strong, and rapid recent advances in test beds with DMs made using microelectromechanical system (MEMS) technology have motivated a number of compelling mission concepts that set technical specifications for their use as wavefront controllers. This research will advance the technology readiness of the MEMS DMs components that are currently at the forefront of the field, and the project will be led by the manufacturer of those components, Boston Micromachines Corporation (BMC). The project aims to demonstrate basic functionality and performance of this key component in critical test environments and in simulated operational environments, while establishing model-based predictions of its performance relative to launch and space environments. Presented will be the current status of the project with modeling and initial test results.

344.04 – Telescope Design for a Space-Based Gravitational-Wave Observatory

Jeffrey C. Livas[1]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States.

Space-based Gravitational-wave Observatories will enable the systematic study of the low-frequency band (0.0001 - 1 Hz) of gravitational waves, where a rich array of astrophysical sources is expected but the motion of the ground is too large to permit construction of a sensitive detector below about 10 Hz. Optical telescopes play an important role in the measurement of gravitational waves in space, but for displacement measurement, not for imaging. They deliver laser light efficiently from one sciencecraft to another over million-kilometer scale separations and both transmit and receive light simultaneously. Transmitting and receiving at the same time puts tight constraints on the scattered light performance because the displacement measurement is made with heterodyne interferometry. Furthermore, there are two telescopes directly in the measurement path between each pair of sciencecraft, so each one requires picometer/√Hz dimensional stability in the measurement band. We report on the performance requirements and design trade-offs required to turn a telescope of modest size and conventional design into a key element of a precision optical metrology system, with an emphasis on the two requirements, optical pathlength stability and scattered light performance, that are beyond the usual specifications for high quality image formation. This work funded in part by NASA SAT grant 11-SAT11-0027 as part of solicitation NNH11ZDA001N.

344.05 – Demonstrating Enabling Technologies for the High-Resolution Imaging Spectrometer of the Next NASA X-ray Astronomy Mission

Caroline Kilbourne[1], Joseph S. Adams[1], Simon Bandler[1], James Chervenak[1], Meng Chiao[1], Randy Doriese[2], Megan Eckart[1], Fred Finkbeiner[1], Joseph W. Fowler[2], Gene Hilton[2], Kent Irwin[3], Richard L. Kelley[1], Samuel J. Moseley[1], Frederick S. Porter[1], Carl Reintsema[2], John Sadleir[1], Stephen J. Smith[1], Daniel Swetz[2], Joel Ullom[2]
1. NASA GSFC, Greenbelt, MD, United States. 2. NIST – Boulder, Boulder, CO, United States. 3. Stanford University, Stanford, CA, United States.

NASA/GSFC and NIST-Boulder are collaborating on a program to advance superconducting transition-edge sensor (TES) microcalorimeter technology toward Technology Readiness Level (TRL) 6. The technology development for a TES imaging X-ray microcalorimeter spectrometer (TES microcalorimeter arrays and time-division multiplexed SQUID readout) is now at TRL 4, as evaluated by both NASA and the European Space Agency (ESA) during mission formulation for the International X-ray Observatory (IXO). We will present the status of the development program. The primary goal of the current project is to advance the core X-ray Microcalorimeter Spectrometer (XMS) detector-system technologies to a demonstration of TRL 5 in 2014. Additional objectives are to develop and demonstrate two important related technologies to at least TRL 4: position-sensitive TES devices and code-division multiplexing (CDM). These technologies have the potential to expand significantly the range of possible instrument optimizations; together they allow an expanded focal plane and higher per-pixel count rates without greatly increasing mission resources. The project also includes development of a design concept and critical technologies needed for the thermal, electrical, and mechanical integration of the detector and readout components into the focal-plane assembly. A verified design concept for the packaging of the focal-plane components will be needed for the detector system eventually to advance to TRL 6. Thus, the current project is a targeted development and demonstration program designed to make significant progress in advancing the XMS detector system toward TRL 6, establishing its readiness for a range of possible mission implementations.

344.06 – Physics of the Cosmos (PCOS) Technology Development Program Overview

B. Thai Pham[1], Mark Clampin[1], Russ L. Werneth[1]
1. NASA, Greenbelt Md, MD, United States.

The Physics of the Cosmos (PCOS) Program Office was established in FY11 and resides at the NASA Goddard Space Flight Center (GSFC). The office serves as the implementation arm for the Astrophysics Division at NASA Headquarters for PCOS Program related matters. We present an overview of the Program's technology management activities and the Program's technology development portfolio. We discuss the process for addressing community-provided technology needs and the Technology Management Board (TMB)-vetted prioritization and investment recommendations. This process improves the transparency and relevance of technology investments, provides the community a voice in the process, and leverages the technology investments of external organizations by defining a need and a customer. Goals for the PCOS Program envisioned by the National Research Council's (NRC) "New Worlds, New Horizons in Astronomy and Astrophysics" (NWNH) Decadal Survey report include science missions and technology development for dark energy, gravitational waves, X-ray, and inflation probe science.

344.07 – Cosmic Origins (COR) Technology Development Program Overview

Russell Werneth[1], B. Thai Pham[1], Mark Clampin[1]
1. NASA, Greenbelt Md, MD, United States.

The Cosmic Origins (COR) Program Office was established in FY11 and resides at the NASA Goddard Space Flight Center (GSFC). The office serves as the implementation arm for the Astrophysics Division at NASA Headquarters for COR Program related matters. We present an overview of the Program's technology management activities and the Program's technology development portfolio. We discuss the process for addressing community-provided technology needs and the Technology Management Board (TMB)-vetted prioritization and investment recommendations. This process improves the transparency and relevance of technology investments, provides the community a voice in the process, and leverages the technology investments of external organizations by defining a need and a customer. Goals for the COR Program envisioned by the National Research Council's (NRC) "New Worlds, New Horizons in Astronomy and Astrophysics" (NWNH) Decadal Survey report includes a 4m-class UV/optical telescope that would conduct imaging and spectroscopy as a post-Hubble observatory with significantly improved sensitivity and capability, a near-term investigation of NASA participation in the Japanese Aerospace Exploration Agency/Institute of Space and Astronautical Science (JAXA/ISAS) Space Infrared Telescope for Cosmology and Astrophysics (SPICA) mission, and future Explorers.

344.08 – Recent progress in adjustable X-ray optics for astronomy

Paul B. Reid[1], Ryan Allured[1], Vincenzo Cotroneo[1], Stuart McMuldroch[1], Vanessa Marquez[1], Daniel A. Schwartz[1], Alexey Vikhlinin[1], Stephen L. O'Dell[2], Brian Ramsey[2], Susan Trolier-McKinstry[3], Raegan Johnson-Wilke[3], Rudeger H. Wilke[3]
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Two adjustable X-ray optics approaches are being developed for thin grazing incidence optics for astronomy. The first approach employs thin film piezoelectric material sputter deposited as a continuous layer on the back of thin, lightweight Wolter-I mirror segments. The piezoelectric material is used to correct mirror figure errors from fabrication, mounting/alignment, and any ground to orbit changes. The goal of this technology is to produce Wolter mirror segment pairs corrected to 0.5 arc sec image resolution. With the combination of high angular resolution and lightweight, this mirror technology is suitable for the Square Meter Arc Second Resolution Telescope for X-rays (SMART-X) mission concept.. The second approach makes use of electrostrictive adjusters and full shell nickel/cobalt electroplated replication mirrors. An array of radial adjusters is used to deform the full shells to correct the lowest order axial and azimuthal errors, improving imaging performance from the 10 – 15 arc sec level to ~ 5 arc sec. We report on recent developments in both technologies. In particular, we discuss the use of in-situ strain gauges on the thin piezo film mirrors for use as feedback on piezoelectric adjuster functionality, including their use for on-orbit figure correction. We also report on the first tests of full shell nickel/cobalt mirror correction with radial adjusters.

344.09 – Toward Directly-Deposited Optical Blocking Filters for High-performance, Back-illuminated Imaging X-ray Detectors

Mark W. Bautz[1], Steven E. Kissel[1], Kevin Ryu[2], Vyshnavi Suntharalingam[2]
1. MIT, Cambridge, MA, United States. 2. MIT Lincoln Laboratory, Lexington, MA, United States.

Silicon X-ray detectors require optical blocking filters to prevent out-of-band (UV, visible and near-IR) radiation from corrupting the X-ray signal. Traditionally, blocking filters have been deposited on thin, free-standing membranes suspended over the detector. Free-standing filters are fragile, however, and in past instruments have required heavy and complex vacuum housings to protect them from acoustic loads during ground operations and launch. A directly-deposited blocking filter greatly simplifies the instrument and in principle permits better soft X-ray detection efficiency than a traditional free-standing filter. Directly-deposited filters have flown in previous generation instruments (e.g. the XMM/Newton Reflection Grating Spectrometer) but none has yet been demonstrated on a modern, high-performance back-illuminated X-ray CCD. We report here on the status of our NASA-funded Strategic Astrophysics Technology program to demonstrate such filters.

344.10 – The Next Generation of X-Ray Reflection Gratings

Randall L. McEntaffer[1]
1. University of Iowa, Iowa City, IA, United States.
Contributing teams: The Off-Plane X-ray Grating Spectrometer Team

Future NASA X-ray Observatories will shed light on a variety of high-energy astrophysical phenomena. Off-plane reflection gratings can be used to provide high throughput and spectral resolution in the 0.3-2.0 keV band, allowing for unprecedented diagnostics of energetic astrophysical processes. A grating spectrometer consists of multiple aligned gratings intersecting the converging beam of a Wolter-I telescope. To achieve the performance requirements of future missions, these gratings must have a high precision, custom groove profile and be aligned overlap each spectrum at the focal plane. Here we report on the progress made on the development of these gratings during a recent NASA Strategic Astrophysics Technology grant.

We have identified a novel grating fabrication method and have performed X-ray testing of prototype gratings. The performance of these gratings is consistent with high throughput and resolution. Furthermore, we have quantified our alignment tolerances and investigated alignment strategies and module mounts.

344.11 – Progress with NASA Technology Development for Exoplanet Missions (TDEM)

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1. Jet Propulsion Laboratory, Pasadena, CA, United States.
Contributing teams: Exoplanets, technology, coronagraphs, starshades

One of the three components of NASA's Strategic Astrophysics Technology (SAT) solicitation is Technology Development for Exoplanet Missions (TDEM). This poster describes recently funded efforts, their research goals, and the progress that has been made. The focus of technology planning within the Exoplanet Exploration Program has been to demonstrate technologies of starlight suppression that would enable the detection of the spectra of faint nearby exoplanets and in particular biosignatures in the spectra of Earth-like planets. Numerous different technologies have been developed including those for coronagraphs and starshades. The TDEM component of the SAT solicitation is specifically devoted to funding technology efforts in these areas, including contrast demonstrations, research into detectors, the development of deformable mirrors, and advanced modeling efforts. These efforts are described here.

344.12 – Colloid Microthruster Feed System Development for Fine Pointing and Drag-Free Control of Multi-Year Astronomical Observatories

John Ziemer[1], Juergen Mueller[1], Douglas Spence[2], Vlad Hruby[2]
1. Jet Propulsion Laboratory, Pasadena, CA, United States. 2. Busek Co., Inc., Natick, MA, United States.

A new Colloid Microthruster feed system, including a propellant tank and redundant Microvalves, is being developed for fine pointing and drag-free operations of multi-year astronomical observatories under the PCOS SAT program. Almost all Gravitational Wave Observatory (GWO) concepts require microthrusters to maintain a drag-free environment for the inertial sensor instrument to meet the mission science objectives. The current state-of-the-art microthruster in the US is the Busek Colloid Micro-Newton Thruster (CMNT) originally developed under the New Millennium Program for the Space Technology 7 (ST7) and ESA's LISA Pathfinder (LPF) technology demonstration mission. The ST7 CMNT design includes a bellows propellant storage tank that is sized to provide up to 90 days of maximum thrust (30 µN). The new propellant tank is based on a blow-down, metal-diaphragm spherical tank design with enough capacity for a 5-year GWO mission. The new feed system will also include the third generation of Busek's Microvalve, currently being developed under a NASA Phase II SBIR. The Microvalve is responsible for the picoliter per second control of the propellant from the tank to the thruster head, demanding parts with micron-level tolerances, critical alignments, and challenging acceptance test protocols. This microthruster system could also be considered for replacement of reaction wheels for slewing and fine pointing of other astronomical observatories, including Exo-Planet Observatory concepts. The goal of the PCOS SAT effort is to raise the new system to TRL 5 with performance and environmental testing within the next two years.

344.13 – Testing Starshade Manufacturing and Deployment Through NASA's Technology Development for Exoplanet Missions Program

N. J. Kasdin[1], Stuart Shaklan[2], Doug Lisman[2], Mark Thomson[2], Eric Cady[2], Amy Lo[3], Bruce Macintosh[4]
1. Princeton University, Princeton, NJ, United States. 2. Jet Propulsion Laboratory, Pasadena, CA, United States. 3. Northrop Grumman Aerospace Systems, Redondo Beach, CA, United States. 4. Lawrence Livermore National Laboratory, Livermore, CA, United States.

An external occulter is a satellite employing a large screen, or starshade, that flies in formation with a spaceborne telescope to provide the starlight suppression needed for detecting and characterizing exoplanets. Among the advantages of using an occulter are the broadband allowed for characterization and the removal of light before entering the observatory, greatly relaxing the requirements on the telescope and instrument. In this poster we report on the results of our two Technology Development for Exoplanet Missions (TDEM) studies. In the first we examined the manufacturability and metrology of starshade petals, successfully constructing a full size petal from flight like materials and showing through precise edge shape measurements that an occulter made with petals consistent with the measured accuracy would achieve close to 10^-10 contrast. Our second TDEM tested the deployment precision of a roughly half-scale starshade. We demonstrated the deployment of an existing deployable truss outfitted with four sub-scale petals and a custom designed central hub. We showed that the system can be deployed multiple times with a repeatable positioning accuracy of the petals better than the requirement of 1.0 mm. The combined results of these two TDEM projects has significantly advanced the readiness level of occulter technology and moved the community closer to a realizable mission.

344.14 – High Contrast Phase Occulted Visible Nulling Coronagraph for Arbitrary Telescope Apertures

Richard Lyon[1], Mark Clampin[1]
1. NASA/Goddard Space Flight Center, Greenbelt, MD, United States.

The phase-occulted visible nulling coronagraph is a new and scientifically high payoff approach to exoplanet coronagraphy. It is based on using constructive and destructive interference from a modified Mach-Zehnder interferometer, aka a muller. It uses a single interferometer to achieve theta to the 4 power or higher nulling such that on-axis starlight is ejected through the wavefront control channel, aka bright output channel, and off-axis planet light exits the science channel. The higher order dark hole is achieved by varying a small amount the plate scale difference between the two arms of the nuller. The shape of this plate scale can be controlled in 3 different ways such that the high contrast imaging is in principle achieved broadband and for both polarizations simultaneously and it is independent of the telescope aperture shape. Additionally it has a novel wavefront control system to be discussed.

344.15 – Achieving High Contrast for Exoplanet Imaging with a Kalman Filter and Stroke Minimization

A J Eldorado Riggs[1], Tyler D. Groff[1], N. J. Kasdin[1], Alexis Carlotti[1], Robert J. Vanderbei[1]
1. Princeton University, Princeton, NJ, United States.

High contrast imaging requires focal plane wavefront control and estimation to correct aberrations in an optical system; non-common path errors prevent the use of conventional estimation with a separate wavefront sensor. The High Contrast Imaging Laboratory (HCIL) at Princeton has led the development of several techniques for focal plane wavefront control and estimation. In recent years, we developed a Kalman filter for optimal wavefront estimation. Our Kalman filter algorithm is an improvement upon DM Diversity, which requires at least two images pairs each iteration and does not utilize any prior knowledge of the system. The Kalman filter is a recursive estimator, meaning that it uses the data from prior estimates along with as few as one new image pairs per iteration to update the electric field estimate. Stroke minimization has proven to be a feasible controller for achieving high contrast. While similar to a variation of Electric Field Conjugation (EFC), stroke minimization achieves the same contrast with less stroke on the DMs. We recently utilized these algorithms to achieve high contrast for the first time in our experiment at the High Contrast Imaging Testbed (HCIT) at the Jet Propulsion Laboratory (JPL). Our HCIT experiment was also the first demonstration of symmetric dark hole correction in the image plane using two DMs--this is a major milestone for future space missions. Our ongoing work includes upgrading our optimal estimator to include an estimate of the incoherent light in the system, which allows for simultaneous estimation of the light from a planet along with starlight. The two-DM experiment at the HCIT utilized a shaped pupil coronagraph. Those tests utilized ripple style, free-standing masks etched out of silicon, but our current work is in designing 2-D optimized reflective shaped pupils. In particular, we have created several designs for the AFTA telescope, whose pupil presents major hurdles because of its atypical pupil obstructions. Our research in coronagraphy and wavefront control and estimation are improving our readiness for a space-based mission to image exoplanets at high contrast.

345 – Young Stellar Objects Poster Session

Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

345.01 – The Brood of the Swan: A Multigenerational Stellar Population in M17?

Natalie Sanchez[1], Matthew S. Povich[1]
1. Cal Poly Pomona, Pomona, CA, United States.

The M17 nebula, one of our galaxy's youngest, brightest, most massive and nearby star formation regions, features a prominent HII region and expansive giant molecular cloud (GMC). The young stellar population in M17 is characterized by a massive, main cluster within the HII region and a more dispersed and extended population enclosed by a large, shell-like structure of the GMC. This two-component population raises the possibility of triggered star formation within the nebula. We have analyzed the X-ray and infrared-excess young stellar populations to assess whether the relative masses and ages of the extended and clustered populations differ and whether this can develop a clearer picture of M17's evolution.

345.02 – Mid-Infrared Variability in Several Star Formation Regions.

Scott J. Wolk[1], Hans Moritz Guenther[1], Katja Poppenhaeger[1], Jan Forbrich[2, 1]
1. SAO, Cambridge, MA, United States. 2. University of Vienna, Vienna, Austria.
Contributing teams: The YSOVAR Team

We present an analysis of mid-infrared time-series photometry for several clusters taken as part of the Spitzer Young Stellar Object variability program (YSOVAR). In the clusters L1688, IRAS 20050-2720 and GGD 12-15 we identify variability in several hundred stars ranging from Class I to Class III. The data have with photometric uncertainty better than 0.05 mag down to [4.5] ~ 15.5. We study the light curves and color trajectories of the sources in the monitored fields in detail. We investigate the variability and periodicity of the YSOs and find that they divide into observational classes which at a minimum include: 1) stochastic variables, 2) long-term variables, 3) periodic stars which vary in frequency of amplitude and 4) stars with periodic variability stable over long timescales. Some YSO variability defies simple classification. We describe how this variability may be due to both dynamic and rotational changes in inner disk structure and accretion rate.

345.03 – Young, Subarcsecond Binaries: Laboratories for Early Stellar and Circumstellar Disk Evolution

Lisa A. Prato[1]
1. Lowell Observatory, Flagstaff, AZ, United States.

The stars in close (<100 AU), young (few Myr old) binaries experience identical initial conditions during formation and evolution and share identical ages and compositions. However, photometric observations and high-resolution (R~30,000), infrared spectroscopy reveal a number of unexpected differences between stars of similar mass. In some cases stars of apparently identical effective temperatures differ in brightness by a factor of two, for some pairs the projected rotation velocities differ by tens of km/s, and for others the evolutionary state of one star appears to be far more advanced than that of the other in terms of veiling, strong accretion signatures, and infrared excess. In this poster I present some initial results from an on-going study of ~100 close, young binary stars and their detailed properties such as effective temperature, radial velocity, vsini, veiling, surface gravity, accretion rate, magnetic field, and crude inner disk structure, and speculate as to the origins of the sometimes baffling differences observed in these properties within pairs.

345.04 – How Cool Is That? An IRTF/SPEX Spectroscopic Study of the Close Binary T Tauri System V4046 Sgr

Carter-Thaxton Smith[1, 2], Valerie Rapson[2], Benjamin A. Sargent[2], Joel H. Kastner[2], John Rayner[3]
1. University of Arizona, Tucson, AZ, United States. 2. Rochester Institute of Technology, Rochester, NY, United States. 3. NASA Infrared Telescope Facility, Honolulu, HI, United States.

We have obtained near-IR (1-5 micron) spectroscopy of the nearby, close binary T Tauri system V4046 Sgr AB with the NASA Infrared Telescope Facility (IRTF) SPEX spectrometer. Our motivation is to assess the potential discrepancies between optical and near-IR spectral classifications of this and other young, late-type stars. Such (optical vs. near-IR) spectral type discrepancies have important implications for the application of pre-main sequence (pre-MS) evolutionary tracks to infer the ages and masses of pre-MS stars; V4046 Sgr AB provides an important test case in this regard, due to the stringent constraints on its system mass (a total of ~1.8 Msun, with roughly equal-mass components) that are imposed by interferometic CO imaging of its extended circumbinary disk combined with its relatively well-determined age (~12 Myr) and distance (~73 pc). We performed equivalent width measurements of diagnostic absorption lines and broad scaling relation measurements to facilitate comparisons between our SPEX near-IR observations and those of IRTF spectral standards. Our preliminary results point to a composite near-IR spectral type for V4046 Sgr AB that is later than the (mid-K) type previously determined from optical spectroscopy. This discrepancy is consistent with that found for other T Tauri stars (most notably, for

TW Hya), emphasizing the need for caution in relying on a specific wavelength regime to obtain pre-MS stellar spectral classifications and (hence) determinations of pre-MS age and mass. Support for this research is provided by by National Science Foundation grant AST-1108950 to RIT C.T. Smith's research at RIT was supported by a NSF Research Experience for Undergraduates program grant to RIT's Chester F. Carlson Center for Imaging Science.

345.05 – Pulsed Accretion in Young Stellar Objects: A Tale of Two Binaries

James Muzerolle[1], Kevin M. Flaherty[2], Zoltan Balog[3], Tracy L. Beck[1], Elise Furlan[4], Robert A. Gutermuth[5]
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We present results of a multi-epoch monitoring campaign of two young stellar objects that exhibit evidence for binary-induced pulsed accretion. Previous observations and theoretical simulations have shown that close binary systems with particular orbital architectures can exhibit periodic increases in accretion activity that correlate with periastron passages. We are studying two such objects with the goal of understanding the dynamical effects of binaries on circumbinary disks. One system is the spectroscopic binary T Tauri star DQ Tau, which is the prototype of the class and is known to exhibit accretion pulses as measured by optical diagnostics; however, its time-dependent behavior in the infrared, which provides a direct tracer of dust emission from circumstellar material, has not been characterized. The other system is the recently-discovered periodically variable protostar LRLL 54361, which has no previous direct measurements of its accretion activity or stellar properties. Our observations include photometry and spectroscopy across a wide range of wavelengths in the optical and infrared. Ultimately, we hope to elucidate the nature of the circumstellar/binary structures in these two systems that span a range of pre-main sequence evolutionary states. This will help establish a framework for understanding some of the infrared variability seen in young stars, and is also of great importance for understanding planet formation processes in binary systems.

345.06 – YSOVAR: The Age of the Cepheus C Star Cluster

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Contributing teams: YSOVAR

We constructed a spectroscopic Hertzsprung-Russell diagram for the Cepheus C (Ceph C) sub-cluster, which we use to generate the first quantitative measurement of this young cluster's age. Using two TripleSpec spectrographs, on the 3.5m telescope at Apache Point Ob- servatory and the 200" telescope at Palomar Observatory, we obtained near infrared (NIR) spectra for 31 candidate Ceph C members. By comparing our target spectra to a large library of dwarf, sub-giant, and giant star templates, we measured spectral types for candidate Ceph C members ranging from F2 to M2.5. We converted each YSO's ST into a Teff estimate using the ST to Teff relation recently published by Pecaut et al. (2013). Using our spectroscopically derived extinction estimates to deredden spectral energy distributions constructed from 2MASS and Spitzer photometry, we measured each YSO's bolometric luminosity. Placing each candidate Ceph C member on an HR Dia-gram, we used Dartmouth pre-main sequence evolutionary tracks to estimate the mass and age of each YSO. We measure a median stellar age for the Ceph C cluster of ?10 Myrs or less. We also detect a large systematic effect in our ages, however, such that cooler, low mass mem- bers have substantially smaller inferred ages than their higher mass counterparts. We are working to understand the root cause of this systematic effect, but this first estimate of Ceph C's age will advance our understanding of the cluster's relationship to other sub clusters in Cepheus, and place the Ceph C cluster in context among other local star forming regions. This research was funded by the NSF through grant number AST-1004107.

345.07 – YSOVAR: Young Star Variations on Timescales of Years

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Contributing teams: YSOVAR team

YSOVAR (Young Stellar Object VARiability) is the name of a group of Spitzer Space Telescope programs (PI: J. Stauffer) all aimed at time-series monitoring of young stars. We have extensive mid-infrared (3.6, 4.5 um) time-series photometry of a dozen star-forming regions on a variety of timescales ranging from minutes to years. This poster will summarize the initial results found for variability on the longest timescales to which we are sensitive, 6-7 years.

345.08 – Detection of Masers Toward Young Stellar Objects in the LMC

Adam Johanson[1], Victor Migenes[1]

1. Brigham Young University, Provo, UT, United States.

We present results from a search for water maser emission toward three regions of massive star formation in the Large Magellanic Cloud (LMC). Six water maser spots were detected toward two of the regions, including one region with no known previous emission. Many of the maser spots are found to be associated with known massive young stellar objects (YSOs). One maser spot appears to identify a previously unknown massive YSO. Another maser spot appears to be associated only with a filament due to local enhancement of the interstellar medium. We argue that this may be the first extragalactic maser associated with a low-mass YSO. The third region hosts a newly discovered 22 GHz continuum source, also associated with a massive YSO. Our results illustrate the usefulness of masers as probes of the star formation process, both at a local and galactic scale. We also present results of a search for methanol masers toward massive YSOs in the LMC.

345.09 – Study of the Outflow and Disk surrounding a Post-Outburst FU-Orionis Star

Samuel N. Mellon[1], Laura M. Perez[2]
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PP 13 is a fan-shaped cometary nebula located in the constellation of Perseus and embedded in the L1473 dark cloud. At optical wavelengths this region is obscured by the surrounding dark cloud, while at infrared and longer wavelengths two northern objects (PP13Na & PP13Nb) and one southern object (PP13S) are revealed. In the past, the young stellar object inside PP13S, called PP13S*, experienced an FU-Orionis type outburst due to a massive accretion episode and is currently returning to its quiescent state. Studying the FU-Orionis phase is crucial to our understanding of how low mass stars form; it is theorized that all low-mass stars go through this outburst phase while they are forming. I used CARMA 3mm interferometric observations of the PP13 region to study the continuum and molecular line emissions from PP13. With these observations, I determined the source of the previously detected outflow and learned new information about the double star system PP13Na and PP13Nb. Although I was not able to detect the accretion disk in the gas emissions, I plan to use computer modeling to help provide constraints on the properties of PP13S* and its outflow.

345.10 – Heating the Primordial Soup: X-raying the Circumstellar Disk of T Cha

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The classical T Tauri Star (cTTS) T Chamaeleontis (T Cha) presents a unique opportunity to probe pre-main sequence star-disk interactions and late-stage circumstellar disk evolution. T Cha is the only known example of a nearly edge-on, actively accreting star/disk system within ~110 pc, and furthermore may be orbited by a low-mass companion or massive planet that has cleared an inner hole in its disk. The star is characterized by strong variability in the optical (~3 magnitudes in the V band) as well as large and variable extinction (AV in the range of 1-5). Like most cTTS, T Cha is also a luminous X-ray source. We present preliminary results of two observations (totaling 150 ks) of T Cha with Chandra's HETGS. Our motivations are to (a) determine the intrinsic X-ray spectrum of T Cha, so as to establish whether its X-ray emission can be attributed to accretion shocks, coronal emission, or a combination; (b) investigate whether its X-ray flux exhibits modulation that may be related to the stellar rotational period (~3.3 days); and (c) take advantage of the nearly-edge-on disk viewing geometry to model the spectrum of X-rays absorbed by the gaseous disk orbiting T Cha. These results will serve as much-needed input to models of magnetospheric accretion and irradiated, planet-forming disks. This research is supported via award number GO3-14022X to RIT issued by the Chandra X-ray Observatory Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of NASA under contract NAS803060. Additional support is provided by National Science Foundation grant AST-1108950 to RIT.

345.11 – X-ray and Characteristic Properties of Young Stellar Objects Identified in NGC 3576

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NGC 3576 is a giant HII region in the Carina spiral arm that has been suggested to be the youngest component of the Carina complex, which is a chain of sequential, possibly triggered, star formation. The complex (D ~ 2.3 kpc) contains 8 open clusters with at least 66 O stars, 3 Wolf-Rayet stars, and the variable Eta Carina. In order to test for triggering, a complete census of young stellar objects (YSOs) is needed to find the timescales of star formation and relationships in age between different populations within the Carina complex. We investigate the usefulness of X-ray surveys in identifying low mass YSOs in NGC 3576 by comparing the properties of sources detected by Spitzer in the mid-infrared and by Chandra in X-rays. We reliably identified and classified YSOs by fitting a collection of radiative transfer model spectral energy distributions (SEDs)

to their infrared photometry based on the technique in Robitaille et al. (2007). We then compared the stage distribution, bolometric luminosity, total mass, disk mass, and mass accretion of YSOs that were detected by Chandra to those without Chandra detections to determine if YSOs identified using X-ray data were statistically different from YSOs identified using infrared data. Finally, we compared the X-ray hardness of YSOs and other sources detected by Chandra to determine the completeness of the YSO census in NGC 3576.

345.12 – A Chandra X-ray Observation of the Jet-Driving T Tauri Star RW Aur

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RW Aur is a multiple T Tauri system consisting of a mid-G/early-K primary (RW Aur A) and a K5 companion (RW Aur B) at a separation of 1.5 arcsecs. The primary drives a bipolar optical jet that has been traced out to 100 arcsecs from the star in [SII] images. We present results of a sensitive Chandra observation of RW Aur. Chandra clearly resolves the pair and reveals that the companion is variable and much brighter in X-rays than the primary. No evidence of X-ray emission from the jet is seen in raw images (no deconvolution) but the jet-driving primary RW Aur A does show a very soft spectral component that may arise in the shocked inner jet close to the star or in an accretion shock. We will compare the X-ray properties of RW Aur A and its companion based on first results from spectral, timing, and image analysis. This work was supported by SAO grant GO3-14007X.

345.13 – Emission Line Profiles in T Tauri Stars

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Emission lines in Classical T Tauri stars often have complex kinematic features that suggest a composite origin. We have begun a line profile analysis for 18 classical T Tauri stars based on simultaneous HIRES and NIRSPEC spectra with the goal of identifying kinematic components in different lines and comparing their line ratios to the local line excitation models of Kwan and Fischer (2011). Decomposition of permitted lines in T Tauri stars into broad and narrow components has been a recognized approach since Hamann and Persson (1992). To date, we have decomposed lines of the Paschen series, Ca II infrared triplet, He I 5876 and OI 8446 into multiple Gaussian components. While some lines have simple Gaussian shapes, others require up to three components to describe the observed profiles. We identify commonalities among these three lines and use ratios of similar kinematic components to explore physical conditions in the line-forming region.

345.14 – A Comparative Study of YSO Classification Techniques using WISE Observations of the KR 120 Molecular Cloud.

Sung-Ju Kang[1], Charles R. Kerton[1]
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KR 120 (Sh2-187) is a small Galactic HII region located at a distance of 1.4 kpc that shows evidence for triggered star formation in the surrounding molecular cloud. We present an analysis of the young stellar object (YSO) population of the molecular cloud as determined using a variety of classification techniques. YSO candidates are selected from the WISE all sky catalog and classified as Class I, Class II and Flat based on 1) spectral index, 2) color-color or color-magnitude plots, and 3) spectral energy distribution (SED) fits to radiative transfer models. We examine the discrepancies in YSO classification between the various techniques and explore how these discrepancies lead to uncertainty in such scientifically interesting quantities such as the ratio of Class I/Class II sources and the surface density of YSOs at various stages of evolution.

345.15 – WISE Identified Young Stellar Objects In BRC 38

John Gibbs[1], Luisa M. Rebull[2], Wendi Laurence[3], Robert Marshall[4], Michael Murphy[5], Laura Orr[6], Christi Whitworth[7], Anna Burton[1], Taylor Corris[1], Sean Goodey[1], Stewart McGinnis[1], Connor Laurence[8], Olivia Aschman[5], Robin Kikuchi [5], Jonathan Prather [5], Lee Whitley[5], Chad Billings[6], Caleb Mader[6]
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Bright rimmed clouds (BRCs) are dense clumps of gas and dust within HII regions at the edges of molecular clouds; while the BRCs themselves are dark, their rims are optically bright from illumination by nearby O or B stars. Many BRCs show

evidence of active star formation possibly triggered by the ionizing radiation from the nearby O or B stars. The large molecular cloud IC1396 is home to eleven BRCs thought to be driven by the O6.5V star HD206267. BRC 38 is located in the north of IC1396, at 21:40:42 +58:16:13. The immediate ~5'x5' region around BRC 38 has been extensively studied in many wavelengths from X-rays to infrared (IR), identifying ~100 young stellar objects (YSOs). We used data from the Wide-field Infrared Survey Explorer (WISE) to expand the search for YSOs to a 20 arcminute radius from the center of BRC 38. Starting with approximately 7000 sources identified in the WISE catalog, we used an updated version of the IR color selection scheme developed by Koenig et al. (2012) to identify ~40 objects having IR colors consistent with those of YSOs; some overlapping with the literature YSO candidates. Combining confirmed and candidate YSOs from literature with those we identified by color selection, we find 115 unique objects of interest. For each of these sources, we analyzed (a) the WISE, 2MASS, and Spitzer images to determine if they were point-like sources; (b) their IR colors to determine if they exhibited a clear IR excess; and (c) their spectral energy distributions (SEDs) to determine if they had an SED shape consistent with their identification as YSO candidates. Our work adds several new YSO candidates to the list of YSOs in and near BRC 38 and newly identifies IR excesses for many of the previously identified YSOs in the region. We looked for evidence of triggered star formation in BRC 38, but are limited in our conclusions by small-number statistics. Support is provided for this work by the NASA/IPAC Teacher Archive Research Program (NITARP), which receives funding from the NASA ADP program and the IPAC archives. A companion paper presenting the educational results of this team's work can be found in another AAS poster by Laurence et al.

345.16 – Evidence for UV Shielding of H₂O in DG Tau

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We analyze the rotational OH spectrum of the T Tauri star DG Tau observed with the Spitzer Space Telescope. OH is observed in emission over the entire wavelength range of the spectrograph, from upper level energies of 1900 to 28,000 K. The rotational diagram cannot be fit with any single temperature-column density component and shows slopes that correspond to excitation temperatures ranging from 200 to 6000 K. We fit the individual OH rotational features to determine the relative λ-doublet population within each rotational level. The λ-doublet levels are not equally populated, showing that the OH is not in thermal equilibrium. There is a propensity for the symmetric λ-doublet state in all rotational levels, with an average of 0.5 for the ratio of the antisymmetric to symmetric state populations. We calculate models for the radiative cascade of OH and discuss how the population distribution of the high rotational lines and the λ-doublet ratio are consistent with the formation of OH following the photo dissociation of H_2O by FUV photons in the second absorption band of water. These results provide evidence for the photodissociation of water and for the possible action of water in shielding molecular gas from FUV radiation.

345.17 – Abundances in the High-Latitude Herbig Ae Star PDS2

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The unusual Herbig Ae star PDS2 (CD -53 251) was noted in the survey by Gregorio-Hetem, et al. (AJ 103, 549, 1992) of the IRAS catalog entries for T Tauri or Herbig Ae/Be stars. It has a high Galactic latitude and is unrelated to any known star-forming region (Vieira, et al. AJ, 126, 2971, 2003). The metallic emission spectrum, common among Herbig Ae/Be stars, is undeveloped in PDS2. Strong, variable H-alpha and He I 10830A emission, have been found e.g. (Hubrig, et al. EDP Sciences, in press). We do see sharp [O I] displaced some 25-30 km/sec to the violet of the photospheric spectrum. Lithium is not identified. An upper limit of Log(Li/Ntot) <= -10.95 was derived by assuming a 1mA 6707A feature. Hubrig, et al. (A\&A, 502, 283, 2009), detected a magnetic field of the order of 100 Gauss, which might could indicate a relation to the magnetic CP stars. We have performed an abundance study based on HARPS and X-shooter spectra. PDS2 is a mid-F star where the effective temperature is indicated by the Balmer line strengths, virtually independent of the surface gravity. The latter may then be found from the first and second spectra of Fe, supplemented in this study by Ti, V, Cr, Mn, and Ni. The first spectra of these elements are nearly independent of surface gravity. The relatively low value of v sin(i), ca. 12 +/- 2 km/sec, allows us to restrict many abundance determinations to lines with equivalent widths less than 40 mA. The stronger lines then yield the microturbulence parameter (1.8 km/sec), crucial when stronger lines must be used. We find Te = 6500K and \logg = 3.5. Abundances are given for 28 elements. We find a pattern similar to that found for HD 101412 in an earlier work (Cowley et al. A\&A, 523, 65, 2010), and confirmed in a larger study by Folsom, et al. (MNRAS, 422, 2072, 2012). Refractory elements are depleted with respect to their solar values, while volatile elements, with the exception of Zn, are normal or mildly enhanced. All determinations are in LTE with the exception of O I, where the solar value was found from the infrared triplet, using NLTE. This overall pattern is more like that of the Lambda Boo than the magnetic CP stars.

345.18 – The curious morphology and orientation of Orion proplyd HST10

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HST10 is one of the largest proplyds in the Orion Nebula and is located approximately 1' SE of the Trapezium stars. Unlike other proplyds in Orion, however, the long-axis of HST10 does not align with theta1 Ori C, but is instead aligned with the rotational axis of the HST10 disk. This cannot be easily explained using current photo-evaporation models. In this poster, we present high spatial resolution ground-based near-infrared images of the Orion proplyd HST-10 using Keck/NIRC2 with the Laser Guide Star Adaptive Optics system along with a multi-epoch analysis of HH objects near HST10 using Hubble Space Telescope WFPC2 and ACS cameras. Our narrow-band near-IR images resolve the proplyd ionization front (IF) and circumstellar disk down to 23 AU at the distance to Orion in Br_gamma, He I, H_2, and PAH emission (3.3 micron). Br_gamma and He I emission primarily trace the ionization front (with the disk showing prominently in silhouette), while the H_2 and PAH emission trace the surface of the disk itself. PAH emission also traces small dust grains within the proplyd envelope which is asymmetric and does not coincide with the IF. Multi-epoch HST images of the HST10 field show proper motion of 3 knots associated with HH 517, clearly indicating that HST10 has a jet and/or outflow. We postulate that the orientation of HST10 is driven by this jet/outflow. Furthermore, we postulate that the curious morphology of the PAH emission may be due to the UV-heating of both sides: one side by theta1 Ori C, and the other by theta2 Ori A.

345.19 – Inferring Magnetic Fields in Low-Velocity Radiative Shocks

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Contributing teams: Patrick Hartigan

Shock waves with velocities less than about 100 km/s occur in many types of astrophysical objects, including jets from young stars and planetary nebulae. Radial velocities and flux ratios of the emission lines in the cooling zones behind these shocks provide a great deal of information both about the flow dynamics and the physical conditions such as electron temperature, density, and ionization fraction. However, a key piece of the puzzle, magnetic field strength, has been difficult to infer because most shocked gas shows no discernible Zeeman splitting or polarization, and the line ratios are degenerate with respect to the field strength. In this work we show that adding the additional constraint of a spatially-resolved cooling-zone size breaks the degeneracy of the line ratio information and makes it possible to estimate Alfvenic Mach numbers of radiative shock waves stellar jets using only quantities that are readily observable. We discuss how the method works, quantify its intrinsic scatter, and apply it to well-known systems that have been studied with HST.

345.20 – The VLA Perseus Young Protostellar Disk and Multiplicity Survey: A First Look

Dominique Segura-Cox[1], John J. Tobin[2], Claire J. Chandler[3], Michael M. Dunham[4], Kaitlin M. Kratter[5], Zhi-Yun Li[6], Leslie Looney[1], Carl Melis[7], Laura M. Perez[3], Sarah Sadavoy[8]
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We present a first look at the Jansky VLA Perseus young protostellar disk and multiplicity survey. The formation of disks and binary systems is generally thought to begin early in the star formation process. However, there have not been sufficient numbers of young protostars (Class 0 and I phases) observed with high enough resolution to determine when and where most binaries form and whether or not large disks are common at early times. To make progress on these problems, we are conducting a multiplicity and disk survey of the 73 known Class 0 and I protostars in the Perseus cloud (d? 230 pc) using the Jansky VLA at 8 mm, 1 cm, 4 cm and 6.6 cm. We will conduct observations in both B and A configurations to resolve features as small as 15 AU (? 0.06''), but with sensitivity to structures as large as ?4'' in size. We have chosen Perseus because it is the nearest star forming region with a large sample of both Class 0 and Class I protostars. This will be the largest and most complete millimeter/centimeter-wave survey of protostellar binaries and disks ever undertaken, with sensitivity to binary separations from ? 5000 AU down to 15 AU and thus sampling the peak of the binary separation distribution (~50 AU) toward protostars for the first time. Moreover, we will be able to resolve disks as small as 30 AU. This survey will significantly improve our understanding of the formation mechanisms and prevalence of close binaries and disks during the early stages of star formation. Here we present our initial results from the B-array observations of the Perseus young protostars.

345.21 – Our Youngest Neighbors: Brown Dwarfs in Nearby Moving Groups

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Contributing teams: BDNYC

To understand brown dwarfs, we must know their ages. Because brown dwarfs do not achieve stable hydrogen fusion, they have no main sequence and no direct mass-luminosity relationship. Instead, brown dwarfs continually change in radius, temperature, and luminosity over time. The BDNYC group is undertaking an extensive study of "red" L dwarfs, objects which exhibit spectral features indicative of low surface gravity and therefore youth. One of the tools at our disposal is connecting these brown dwarfs with nearby (d<100 pc) young (age <200 Myr) moving groups (NYMGs). However, the membership and properties of the NYMGs are in constant flux, with new members and new groups continuously being identified. Moreover, many so-called members, and occasionally their entire groups, have been called into question depending on the technique and criteria used to identify young objects. The BDNYC group has created a compendium of information on all members of nearby moving groups, and we are analyzing and refining this heterogeneous collection to better provide clues about the nature of our local extremely low mass neighbors.

345.22 – Herschel Shines Light on the Episodic Evolutionary Sequence of Protostars

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Contributing teams: DIGIT, FOOSH, and COPS teams

New far-infrared and submillimeter spectroscopic capabilities, along with moderate spatial and spectral resolution, provide the opportunity to study the diversity of shocks, accretion processes, and compositions of the envelopes of developing protostellar objects in nearby molecular clouds. We present the "COPS" (CO in Protostars) sample; a statistical analysis of the full sample of 30 Class 0/I protostars from the "DIGIT" Key project using Herschel-PACS/SPIRE 50-700 micron spectroscopy. We consider the sample as a whole in characteristic spectral lines, using a standardized data reduction procedure for all targets, and analyze the differences in the continuum and gas over the full sample, presenting an overview of trends. We compare the sources in evolutionary state, envelope mass, and gas properties to more evolved sources from the"FOOSH'' (FUor) samples.

345.23 – Time-Series Position-Velocity Diagrams of the Jet and Low-Velocity Components in HH 444

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HH 444 is a collimated YSO jet in Orion notable for a well-defined low-velocity component that merges with a high-velocity component a few arcseconds away from the source. A high-quality position-velocity diagram taken in 2000 (Andrews et al. 2004) shows both a high-velocity jet (HVC) and a low-velocity component (LVC) in the red lines of [S II], H-alpha and [N II]. A bridge of intermediate velocity (IVC) connects the LVC and the HVC. In this poster we report new Keck observations of the system taken a decade later with the same spectrograph but a larger detector. Enough time has now passed since the previous observations to allow us to track proper motions, and thereby learn which features in the position-velocity map of the jet evolve dynamically, and which are static. The new CCD makes more line ratios and diagnostics possible as well. These data represent the most through exploration of the phase space of stellar jets to date, and include temporal, spatial, and radial velocity data for each point in the flow. The new spectra show how jets evolve with time as they emerge from accretion disks. The LVC is dense and mostly neutral near the star, and has no discernible proper motion. The IVC is hot, with a high ionization fraction, but also no proper motion, while the HVC has kinematic signatures and excitations of a jet, with high proper motions, a declining density with distance, and relatively low ionization fraction. Taken together, these data imply that the jet entrains and heats the IVC within a few arcseconds from the star. The HVC drops in velocity where it intersects the IVC, probably owing to mass loading, and there is evidence for a second IVC that connects with the jet at a greater distance from the star.

345.34 – Detection of Radio Outbursts of Young Low-Luminosity Protostars

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Magnetosphere is an integral part of a star and plays important roles in the dynamics of ionized gas in and around the star.The magnetosphere manifests itself through powerful outbursts of energy such as radio and X-ray flares, and such magnetic activities start well before the onset of stable hydrogen burning. The magnetic fields of young stellar objects may be seeded by the interstellar magnetic fields in the natal cloud. However, the origin of stellar magnetic fields has been

difficult to study because class 0 protostars are surrounded by opaque layers of gas that block the radio emission from the view of outside observers. Recently discovered very-low-luminosity protostars may have relatively transparent outer layers and present a new opportunity to directly observe the protostellar magnetic activities. We detected a radio outburst of a class 0 protostar in the Taurus star-forming region. The outburst timescale of 20 days is consistent with magnetic flares. Since this protostar is too young and small to develop an internal convective dynamo, the flare may be caused by the magnetic fields of interstellar origin. Such flares may be a dominant source of high-energy photons around these low-luminosity protostars.

346 – The Milky Way, The Galactic Center Poster Session
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

346.01 – The Radial Velocity Experiment RAVE

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Contributing teams: RAVE collaboration

The Radial Velocity Experiment (RAVE) is an all-sky spectroscopic survey to measure radial velocities and stellar atmosphere parameters (temperature, surface gravity) and abundances of nearly half a million stars using the 6dF multi-object spectrograph on the 1.2-m UK Schmidt Telescope of the Anglo-Australian Observatory (AAO). RAVE is a multi-national endeavour involving scientists from 10 countries. RAVE started in April 2003 and has completed the data taking phase in April 2013. Almost 580 000 spectra have been taken in the Ca-triplet region (8410-8790 Å) for 480 000 southern hemisphere stars in the magnitude range 9 < I < 13 at a resolution of R=7500. The radial velocities measured in this survey are accurate to 2 kilometers per second. RAVE has meanwhile published three data releases, a fourth data release is scheduled for early 2014. Science applications of RAVE include the identification of substructure in the Milky Way and to derive constraints on the gravitational potential of our Galaxy.

346.02 – The Radial Velocity Experiment (RAVE): Fourth Data Release

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Contributing teams: RAVE collaboration

We present the stellar atmospheric parameters (effective temperature, surface gravity, overall metallicity), radial velocities, individual abundances and distances determined for 425 561 stars, which constitute the fourth public data release of the intermediate spectroscopic stellar survey of the RAdial Velocity Experiment (RAVE). Compared to previous RAVE data releases, the present one increases the available catalog size by an order of magnitude. The stellar atmospheric parameters are computed using a new pipeline, based on the algorithms of MATISSE and DEGAS. The spectral degeneracies and the 2MASS photometric information are now better taken into consideration, improving the parameter determination compared to the previous RAVE data releases. The individual abundances for six elements (magnesium, aluminum, silicon, titanium, iron and nickel) are also given, based on a special-purpose pipeline which is also improved compared to that available for the previous data releases. Together with photometric information and proper motions, these data can be retrieved from the RAVE collaboration website and the Vizier database.

346.03 – A new stellar chemo-kinematic relation reveals the merger history of the Milky Way disk

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Contributing teams: RAVE collaboration

I will present a new chemo-kinematic relation involving stellar velocity dispersions, metallicities and α-enhancement, found in two independent large data sets: RAVE giants and SEGUE G-dwarfs. Using simulated data, I will show that these new results offer a way to recover the entire merger history of the Milky Way disk. The particular trends of velocity dispersion as a function of [α/Fe] for different metallicity subpopulations can be related to mergers of diminishing strength perturbing the Milky Way disc throughout its lifetime. Within this interpretation, the properties of these events can be recovered in a differential study.

346.04 – The low metallicity tail of the thick disc seen by RAVE

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Contributing teams: RAVE collaboration

By selecting in the RAVE-DR4 survey the metal-poor stars at distances above the Galactic plane between 1 and 2 kpc, we use a very simplistic approach to identify the thick disc, without assigning probabilistically the targets to one of the Galactic components. We find that the thick disc has an extended metallicity tail going at least down to [M/H]=-2dex, contributing roughly at 3% of the entire thick disc population and having a shorter scale-length compared to the canonical thick disc. These metal-poor thick disc stars follow the correlation between the metallicity and the orbital velocity of the canonical thick disc stars of ~50 km/s/dex. These characteristics imply that at least some thick disc stars have been formed from an almost pristine material, and that radial migration scenario seem unlikely to be the main formation mechanism at the origin of the thick disc.

346.05 – Kinematic Modeling Of The Milky Way Using The RAVE And GCS Stellar Surveys

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Contributing teams: Rave Collaboration

We investigate the kinematic parameters of the Milky Way disc using the Radial Velocity (RAVE) and Geneva-Copenhagen (GCS) stellar surveys. We do this by fitting a kinematic model to the data. Using two distinct Markov Chain Monte Carlo (MCMC) techniques, we investigate the full posterior distributions of the parameters given the data. For RAVE, we restrict ourselves to angular position and radial velocity for each star since these quantities are determined to high accuracy. For GCS, the data consist of the full 6 dimensional phase space but, in contrast to RAVE, are confined to the Solar neighborhood only. We show results using the traditional Gaussian distribution function and compare to the Shu distribution function that handles non-circular orbits more accurately. We investigate the `age-velocity dispersion' relation (AVR) for the three kinematic components ($?\_R, ?\_?, ?\_z$), the radial dependence of the velocity dispersions, the Solar peculiar motion (U_Sun, V_Sun, W_Sun) and the circular velocity (v_c) at the Sun. We investigate models with and without a thick disc. We find that the kinematic parameters derived from RAVE and GCS are in good agreement. The Shu model fits the RAVE data better than the Gaussian model, but a perfect fit could not be found for either model. Furthermore, the Gaussian model predicts a positive radial gradient for the velocity dispersion, while the Shu model does not. The measured Solar peculiar motion, U_Sun=10.5 ±0.13, V_Sun=10.27±0.11, and W_Sun=7.44± 0.09, is in good agreement with estimates of Schonrich et al (2010) but our values for (U_Sun, V_Sun) are slightly lower. We stress that V_Sun is a highly model-dependent quantity and claims of accuracy must be treated with caution. For RAVE, we find that v_c = 212 ±1.4 km/s ; this is a lower bound on the true value as the vertical dependence of asymmetric drift for an isothermal population has been ignored in our analysis.

346.06 – Mapping Tidal Streams and Tails around Galactic Globular Clusters using RAVE

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Contributing teams: RAVE collaboration

Stellar population studies of globular clusters have suggested that the brightest globular clusters in the Galaxy are actually the remnant nuclei of dwarf spheroidal galaxies. If present Galactic globular clusters formed within larger stellar systems, they are likely surrounded by extra-tidal halos and tails made up of stars that were tidally stripped from their parent systems. Also, they would have lost the majority fraction of the initial mass due to their internal and external dynamical effects, such as tidal heating and stripping. This information suggests that surroundings around globular clusters can provide an excellent example of such a structure. We use the Radial Velocity Experiment (RAVE) to search for signatures of tidal tails around the globular clusters prominently featured in the extensive RAVE footprint. Stars with RAVE metallicities, radial velocities and proper motions consistent with the abundance patterns and properties of the cluster are presented for Omega Centauri, NGC 3201, NGC 362, NGC 2808 and NGC 1851. The bright magnitudes of these stars make them easy targets for high resolution follow-up observations, allowing us to carry out chemical tagging to identify (or exclude) stars outside the tidal radius of the cluster as tidal debris. As these clusters are well studied with accurate abundances and distances, the RAVE stars located within the tidal radius of these clusters will also aid in the improvement of the stellar parameters and abundances extracted from the RAVE spectra.

346.07 – Constructing a three dimensional map of the diffuse interstellar band at 862 nm from RAVE data

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Contributing teams: RAVE team

The diffuse interstellar bands (DIBs) are one of the longest standing problems of astronomical spectroscopy. Even-tough these wide and sometimes structured absorption lines in the optical and near-infrared wavelengths were discovered already in 1919 and more than 400 are known today, their physical carriers are yet unknown. We intend to present the first three-dimensional map of the strength of the DIB at 862 nm. It is part of the spectral range observed by the RAVE survey in almost 500,000 spectra. As RAVE spectra have mostly low signal-to-noise ratio, several spectra must be combined in order to achieve a signal-to-noise ratio good enough to be able to measure the DIB profile. The map of the DIB strength will be compared with a similar three dimensional map of the interstellar reddening also assembled from RAVE data. This may be the first three dimensional map of the diffuse interstellar band strength with good prospects for the future spectroscopic surveys that will produce more spectra, with better resolutions and signal-to-noise ratios.

346.08 – Finding ultra-faint dwarf galaxies with RR Lyrae

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More than a dozen ultra-faint dwarf galaxies have recently been discovered around the Milky Way by applying color-magnitude and spatial filtering techniques to the Sloan Digital Sky Survey's point source catalog. These galaxies are roughly a million times less luminous than the Milky Way. Such galaxies provide a unique tracer of dark matter and might actually be the most numerous type of galaxy in the Universe. However, numerous observational biases still severely limit our view of the Milky Way's ultra-faint dwarf galaxy population. These biases include the limited sky coverage of the SDSS, the bias against ultra-faint dwarfs at large distances, and the bias against extremely low surface brightness dwarfs (fainter than 29 mag arcsec^-2). The photometric depth of surveys such as DES and LSST may mitigate some of these biases, although deep broadband photometry will bring new technical challenges to searches for resolved stellar systems. RR Lyrae could provide an avenue to identify new ultra-faint dwarf galaxies that is free from some of these challenges. We explore the utility of RR Lyrae as a tracer of previously unseen dwarfs, in the context of known observational biases and in the context of ongoing time-domain surveys such as the Catalina Real-Time Transient survey. The work on this project has been supported by NSF AST-1151462.

346.09 – Accretion History and Mass of the Milky Way Halo: HST Proper Motions and Keck Spectra

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Contributing teams: HSTPROMO Collaboration, HALO7D Collaboration

The Milky Way (MW) is shrouded in a faint metal-poor stellar halo. Its structure and kinematics provide a unique archaeological record of the MW's formation, past evolution, and accretion history. These data also help us constrain the dark matter mass out to large radii (50 to 100 kpc). The stellar density profile and line-of-sight velocity dispersion profile of the halo are known, but our understanding of the halo is limited by a striking lack of knowledge about the transverse motions of its stars. It is difficult from the ground to determine proper motions (PMs) far outside of the solar neighborhood. We have recently developed techniques for making PM measurements from multi-epoch Hubble Space Telescope (HST) data using distant background galaxies to define an absolute astrometric reference frame. We will obtain very deep (8 to 24 hr integrations) Keck II 10-m telescope/DEIMOS spectra of hundreds of faint Milky Way halo stars with HST-measured proper motions, to measure their line-of-sight velocities and chemical abundances, giving us 6D phase-space information plus chemical abundance information. Our primary fields of interest include the CANDELS HST/MCT program fields GOODS-N, COSMOS, and EGS. These fields are characterized by deep HST photometry at wavelengths ranging from the ultraviolet to the infrared. This dataset, which will be unique even in the era of Gaia, will vastly improve our understanding of the Milky Way structure, evolution and mass in a way that neither the HST proper motions or Keck spectroscopy can do on their own. This research is part of two large collaborations: The HST Proper Motion (HSTPROMO) collaboration and the Halo Assembly in Lambda-CDM: Observations in 7-Dimensions (HALO7D). We acknowledge financial support from the National Science Foundation and NASA.

346.10 – Action-space clustering of tidal streams to infer the Galactic potential

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We present a new method for constraining the Milky Way's gravitational potential by simultaneously fitting multiple tidal streams. This method requires full six-dimensional phase-space information for all stars in the streams, which will be provided by Gaia, but it does not require specific identification of any stream in the data, nor determination of stream membership for any star, nor any physical model of stream formation or morphology. The method works on the principle that the action distribution of stars is most clustered (most informative or least entropic) when the potential used to calculate the actions is closest to the true potential. To measure the amount of clustering we use the Kullback-Leibler Divergence (KLD) or cross-entropy or relative entropy, a measure of information. The KLD has an interpretation as a relative likelihood, so the method can make use of the machinery of probabilistic inference, including especially providing justified uncertainties on parameter estimates. We show for toy Gaia-like data (in a spherical isochrone potential) that maximization of the KLD of the action-space distribution of stars relative to a smoother distribution (product of marginals) can be used to estimate accurately the true values of the potential parameters, with a precision depending on the observational errors and the number and type of streams in the sample.

346.11 – Painting a More Accurate Picture of the Sagittarius Dwarf Tidal Stream

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We are improving the current spatial density profile for the Sagittarius dwarf tidal stream and other tidal streams in the Milky Way halo, using new color corrections to the Sloan Digital Sky Survey and a new statistical model for main sequence turnoff stars absolute magnitude distribution. Using the MilkyWay@home distributed computing platform, we implement a method of maximum likelihood to fit a model to both tidal streams and a smooth component of the halo. With this technique, we currently have one of the most accurate descriptions for part of the Sagittarius dwarf tidal stream's spatial density profile as well as a spatial density profile for part of a second (bifurcated) stream near the Sagittarius dwarf tidal stream, whose origins are not well understood. Along with fitting the width, positions, and orientations of the previously mentioned streams, we also have found that the smooth component of the Milky Way halo is oblate. Using these results, we hope to run N-body simulations of the dwarf galaxy tidal disruption that created the tidal debris to constrain the dark matter profile of the Milky Way galaxy. This research was funded by NSF grant AST 10-09670 and the Rensselaer Center for Open Source Software (RCOS).

346.12 – Testing the Caustic Ring Dark Matter Theory Against Observations in the Milky Way

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We test a particular theory of dark matter, in which dark matter axions form ring "caustics" in the plane of the Milky Way. According to this theory, cold collisionless dark matter particles with angular momentum flow in and out of the Milky Way as it forms. These flows form caustic rings (at the positions of the rings, the density of the flow is infinite) at the locations of closest approach to the Galactic center. We show that the caustic ring dark matter theory reproduces a roughly logarithmic halo, with large perturbations near the rings. We show that the theory can reasonably match the known Galaxy rotation curve. We explore the effects of the caustic rings on dwarf galaxy tidal disruption using N-body simulations. Tidally disrupted galaxies are stripped apart by the gravitational forces of the Milky Way, leaving both leading and trailing streams of stars. We compare the results of the model with observations of tidal streams.

346.13 – LAMOST observations of substructure in bulk velocities of Milky Way disk stars

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We explore the kinematics of ~400,000 F-type stars in the Galactic disk and just outside the Sun's radius using data from the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) survey. LAMOST spectroscopic velocities were combined with proper motions from the PPMXL catalog, for which we have derived corrections to the zero points based in

part on spectroscopically discovered galaxies and QSOs from LAMOST, to derive three-dimensional space velocities for the stellar sample. Stars near the Galactic anticenter exhibit velocity substructures in both the Galactocentric radial and vertical components. The structure is most prominent as an asymmetry across the mid-plane, but also varies azimuthally. In the region within 2 kpc outside the Sun's radius and within 2 kpc of the Galactic midplane, stars above the plane exhibit net outward radial motions with downward vertical velocities, while stars below the plane have roughly the opposite behavior. This is likely the signature of perturbations to the disk by an external agent such as a dwarf galaxy or dark matter subhalo. We briefly show additional science results from the first year of LAMOST survey spectra. This research was supported by NSF grant AST 09-37523.

346.14 – Extending stellar density maps of the Orphan Tidal Stream

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This project involves analyzing data directly off the footprint of the Sloan Digital Sky Survey in order to find the progenitor of the Orphan tidal stream. This stream of stellar debris, known to span distances 20 to 47 kpc from the Sun, is believed to be the remnants of a small dwarf galaxy that is largely disrupted. Images were obtained in the vicinity of this stream from the MOSAIC1.1 camera on the 4-meter Mayall telescope at the Kitt Peak National Observatory. The region observed covers 11 square degrees of sky, approximately 7 square degrees of which have no SDSS data. The area outside the SDSS was selected to explore the increase in density of Orphan stars in this location, discussed in Newberg et al. 2010. The positions and magnitudes of stars outside of the SDSS were calculated and calibrated with both data from the SDSS itself, as well as the USNOB-1 catalog. The resulting Orphan candidates selected from this catalog were used to explore the stellar densities along this stream, providing insight into the nature of its progenitor. This research was supported by NSF grant AST 09-37523.

346.15 – Contributions to the nearby stellar halo of the Milky Way from in situ, kicked-out disk, and accreted populations.

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The formation history of the Milky Way's stellar halo is complex. Both observations and cosmological simulations point to a dual halo comprised of inner and outer halo components. The proportion of in situ, kicked-out disk, and accreted stars to each of these components can illuminate their formation mechanisms. In a spectroscopic study of 1799 M giants, the distribution of radial velocity (RV) as a function of Galactic longitude (l) for these stars shows (1) the expected thick disk population and (2) local metal-rich halo stars moving at high speeds relative to the disk, that in some cases form distinct sequences in RV-l ("RV outliers"). I will present results from a high-resolution spectroscopic study of close to 90 of these M giant RV outliers in the nearby halo of the Milky Way, particularly the interpretation of both alpha and neutron capture elements as a function of metallicity in the context of quantifying the relative contributions of in situ, kicked-out disk, and accreted stars to the nearby halo. The chemical abundance trends of the RV outliers suggest that our sample consists predominantly of stars accreted from infalling dwarf galaxies, with a more moderate fraction of stars likely formed in the Galactic disk and subsequently kicked to higher eccentricity orbits. These results support scenarios where the stellar halo arises from multiple formation mechanisms.

346.16 – Hypervelocity Star Candidates in SEGUE

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We identify candidate hypervelocity stars from the Sloan Extension for Galactic Understanding and Exploration (SEGUE) G and K dwarf samples. Previous searches for hypervelocity stars have only focused on large radial velocities; in this study we also use proper motions to select the candidates. We determine the hypervelocity likelihood of each candidate, considering the significant errors often associated with high proper motion stars via Monte Carlo simulations. Using the observed 6-d positions and velocities, we also calculate the orbits of these candidates in order to determine their place of origin within the Galaxy.

346.17 – Red Runaways

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We present results of a kinematic analysis of high-metallicity late-type dwarfs in SDSS spectroscopic data. These dwarfs, most likely having been generated in the disks of the Milky Way, are fit to phase-space profiles using maximum likelihood methods. Outliers from these kinematic profiles (objects having abnormally high or incongruous velocities related to their neighbors) are then extracted based on stars' individual likelihoods according to these fits. Since these high metallicity dwarfs were probably born close to the midplane, we expect that they obtained outlying phase space properties through some sort of ejection process; as such we then examine these objects in the context of various ejection processes (dynamic binary encounters, supernovae kicks, black hole encounters). This is one of the first studies of runaway and hypervelocity stars in the F-M dwarf regime and is made possible by the advent of million item spectroscopy surveys and machine learning techniques.

346.18 – Exploring Biases and Sample Selection Effects for Chemical Cartography with SDSS-III/APOGEE

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The SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE) is a high resolution, near-IR spectroscopic survey of 100,000 stars spanning from the bulge to the edge of the disk to provide an unprecedented picture of the stellar constitution of the Milky Way. APOGEE provides a new and comprehensive database for constraining and improving models of galaxy evolution by providing accurate chemical and kinematic properties for all major constituent Galactic stellar populations. However, properly exploiting a tool like this requires a detailed understanding of the survey construction, and in particular, the influence of target selection criteria on observed phenomena. Here we focus on the bias and sample selection effects on the APOGEE-derived distribution of chemical abundances across the Milky Way. To this end, we used the Galaxy modeling code TRILEGAL (Girardi et al. 2005) to generate Galactic stellar populations along the same lines of sight observed by APOGEE and simulated real observations by sampling the TRILEGAL model with the APOGEE target selection algorithms to mimic the observed APOGEE sample. Based on these simulated observations, we discuss corrections for the survey selection function and for the metallicity bias due to sample selection and specific features of the present version of the APOGEE chemical abundances pipeline.

346.19 – The Blanco DECam Bulge Survey (BDBS): Status and Early Results

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With a very wide field of view (61 scientifically-active chips in 2013 covering a total of 3 square degrees per pointing) and excellent seeing-limited image quality and multi-filter sensitivity, the the Dark Energy Camera (DECam) on the Blanco 4m is a uniquely capable photometric survey instrument, both in its own right and as a pathfinder for the Large Synoptic Survey Telescope (LSST). We are undertaking a large photometric survey with DECam of the Southern Milky Way Bulge and the core of the Sgr dwarf spheroidal galaxy, with sufficient depth to reach slightly below the main sequence turn-off in SDSS ugrizY filters for just over 200 square degrees over the Southern Bulge (i.e. -10° < l < +10° and -13° < b < -2°). In addition to the main photometric survey with wide dithers, a substantial fraction of our fields are observed with microdithers to enable the use of our dataset in proper motion studies. We present results from our campaign in 2013A (NOAO program N0529-2013A, P.I. Rich), which covers the inner 10°x8° of the bulge as well as a 4°-wide strip along the Bulge minor axis down to b = -13°. We easily reach the main sequence turn-off even in crowded fields < 4° from the mid-plane, and clearly detect bulge horizontal branch stars. Initial analysis suggests that we are achieving sufficient astrometric repeatability to enable useful kinematic investigations through proper motions. We discuss these and other results, and outline the lessons our data suggest for the next generation of wide-and-deep surveys, led by LSST, that are due to come online within the decade.

346.20 – Analyzing the Milky Way's Hot Gas Halo with OVII and OVIII Emission Lines

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We present an analysis of the Milky Way's hot gas halo using archival *XMM-Newton* observations of OVII and OVIII line emission. The emission lines are excellent tracers of gas with temperatures at ~10^6 K, which is characteristic of the Milky Way's circumgalactic medium temperature as well as temperature estimates of the Local Bubble. Our model consists of a spherical β model for the halo gas with a fixed temperature of $10^{6.3}$ K and a constant density Local Bubble with a fixed temperature of $10^{6.1}$ K. We find a statistically significant fit to the OVIII observations by modeling the emission lines with a spherical β model with a normalization of $n_0 r_c^{3\beta} = 1.30 \pm .40 \times 10^{-2}$ cm^{-3}kpc$^{3\beta}$ and β = .49 ± .05. We compare our OVIII fitting results to previous work on the Milky Way's soft X-ray background and find our results are consistent with studies devoted to individual lines of sight. The results are also comparable to similar studies analyzing the Milky Way's circumgalactic medium using X-ray absorption lines. We attempt to fit the OVII emission line observations with a model consisting of halo and Local Bubble emission, but are unable to find a statistically significant fit to the data. This is likely due to the simplicity of our model and we are currently exploring more complex hydrodynamical models to characterize Local Bubble emission.

346.21 – Dust ring at the Camelopardalis and Perseus border

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In Camelopardalis segment of Milky Way, optical, infrared and radio observations reveal the presence of a dust ring with a diameter of about 8 deg, centered at Galactic longitude 152 deg, and Galactic latitude +0.5 deg, at the open cluster NGC 1528 (V. Straizys & V. Laugalys, Baltic Astronomy, vol. 16, 167, 2007). We have started the investigation of this ring with the aim to determine distances of its different segments, applying the Vilnius seven-color photometry. The first results of CCD photometry down to V = 17 mag in the three areas of the ring will be presented. CCD exposures were obtained with the 1.8 m VATT telescope on Mt. Graham and with a broad-field Maksutov-type 35/51 cm telescope at the Moletai Observatory in Lithuania. From the interstellar reddening-free photometric parameters, two-dimensional spectral types, interstellar extinctions and distances for several hundred stars in the investigated areas are determined. The distance to the dust ring will be estimated.

346.22 – Emission lines in the Near-infrared Spectra of the IR Quintuplet Stars in the Galactic Center

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The natures of the five infrared stars for which the Galactic center's "Quintuplet Cluster" were named have long been a mystery, although the pinwheel morphologies of two of them suggest that those two are Wolf-Rayet colliding wind binaries.

Not only does each of the five IR stars suffer the same large interstellar extinction that obscures all objects in the Galactic center, but also each is embedded within its own warm and dusty cocoon. Until recently near-infrared spectra of them have revealed only dust continua steeply rising to long wavelengths. In the J and H bands the Quintuplet stars are very faint due to the high extinction, but the continuum emission from their warm cocoons is much less than at longer wavelengths and lines arising within their dust shells should be relatively more prominent. Here we report the detection of a number of emission lines characteristic of hot and massive stars in 1.0-1.8μm spectra of four of the IR Quintuplet stars. The lines that have been detected to date allow initial classifications of most of these stars.

346.23 – Line Diagnostics Across the Galactic Nucleus from Mid-Infrared Emission Line Mapping

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We present results from a mid-infrared spectroscopic survey of the interstellar medium in the central 200 pc of the Galactic Center (GC) using the Infrared Spectrograph on board the Spitzer Space Telescope. We show line intensity maps for forbidden emission lines and atomic and molecular hydrogen lines over this 200 pc region. The radial velocity curves indicate that the forbidden lines arise in photodissociation regions and adjacent ionized gas at the GC. We find, however, that some of the molecular hydrogen emission, in the lowest excitation lines, arises in molecular clouds along the line of sight. Our results agree with earlier studies over a more restricted area in the GC. We map forbidden line intensity ratios in the GC, and compare them to ratios observed in star-forming galaxies and AGN. We use these diagnostic line intensity ratios to understand properties of the GC interstellar medium such as radiation hardness, metal abundance, ionization parameter, and evidence for or against AGN activity.

346.24 – A pilot study to monitor the Galactic Center for radio transients with the First Station of the Long Wavelength Array

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We present preliminary results from a pilot study to monitor the Galactic Center (GC) for radio transients at low-frequencies with the First Station of the Long Wavelength Array (LWA1). Observations were conducted between May 23 - June 8, 2013 utilizing the full LWA1 station beam correlated with an outlier dipole to form a two-element interferometer in order to resolve out extended Galactic emission. This study focuses on radio-selected transients with timescales from minutes to days, longer than those probed by complementary single-dispersed-pulse type searches. A monitoring campaign with LWA1 builds upon successful GC monitoring programs at 330 MHz and 235 MHz with both the VLA and the GMRT, respectively. While there exists a long-established phenomenology of variability in the radio sky, wide-field radio transient surveys of the sky have been rare, and most variable radio sources have been found as a result of following-up X-ray transients and gamma-ray bursts. Long wavelength (>~1 m) observations provide a naturally wide field-of-view, and are well suited for detecting the generally non-thermal emission from radio transients. Our preliminary results indicate we can constrain enhanced emission below 100 MHz from within a few degrees towards the GC that are significant with respect to reasonable extrapolations of previously detected VLA and GMRT non-thermal transients at higher frequencies.

346.25 – Simulating the effect of the \sgra accretion flow on the appearance of G2 after pericenter.

Aleksander Sadowski[1], David Abarca[1], Lorenzo Sironi[1]
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We study the dynamical interaction of the G2 cloud with the accretion flow around Sgr A* by means of three-dimensional, hydrodynamic simulations. We show the effects of the rotating accretion flow on the evolution of G2 by projecting the cloud density onto the plane of the sky, and extracting position-velocity diagrams. We study a number of possible orientations of the cloud orbit with respect to the disk. We find that once the center of mass of the cloud has crossed the pericenter, the differences between models becomes significant. Models with the cloud counter-rotating with respect to the disk are expected to reach higher blue-shifted line of sight velocities. The spatial extent of the emission depends strongly on the cloud-to-disk inclination angle. Future imaging and spectroscopy of G2 emission will shed light both on the structure of the \sgra disk and on the properties of the cloud.

346.26 – Transient Events in Archival VLA Observations of the Galactic Center

Anirudh Chiti[1], Shami Chatterjee[1], Robert Wharton[1], James M. Cordes[1], Joseph Lazio[2], David L.

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A number of different classes of stars, sub-stellar objects, and stellar remnants exhibit variability at radio wavelengths on time scales ranging from sub-seconds to hours. The direction toward the Galactic center not only has the highest stellar densities in the Galaxy, but also appears to have a range of interstellar scattering properties that may aid in the detection of new, radio-selected transient events. We have examined all archival VLA observations of the Galactic center field from 1985 to 2005 at 5 GHz and 8.4 GHz for a total of 214 hours of integration time, spanning 99 observations at 5 GHz with a typical area of 4.41E-4 square degrees and 116 observations at 8.4 GHz with a typical area of 8E-4 square degrees. We used a pipeline to search for transient events down to the shortest time scales allowed by the data (typically 10 seconds) by generating model-subtracted visibility data for each observation and then imaging the residual visibilities over short time intervals to search for outlier events. We present one radio transient event and at least 7 other promising candidates with significances ranging from 5.6 to 10.2 sigma that have passed all our tests, and discuss the possible source classes for these candidates and the event rate implications. We acknowledge support from the National Science Foundation for this work. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

346.27 – Radio Observations of Star Formation in the Galactic Center

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Star formation in the inner regions of the Galactic Center differs strongly from star formation in the Galactic disk. In order to see how environment plays a role in star formation, we must look at several stages of star formation, including past, current, and future star formation. In this study we looked at multiple star forming regions in the inner 50 parsec region of the Galactic Center that trace these different stages, using the VLA and CARMA observatories. We present broadband continuum images of these regions. Since we are using multiple frequencies we can map the spectral index to obtain a better understanding of the physical processes taking place. We also present many molecular line transitions that allow us to trace the temperatures and physical conditions of these extreme environments.

346.28 – Monitoring for Low Frequency Radio Transients in the Galactic Center

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We present initial results from a September 2013 - May 2014 VLA program to monitor for low frequency Galactic center radio transients (GCRTs). In our earlier search for radio-selected transients toward the Galactic center with the legacy VLA and the GMRT, we found three transients. They had disparate properties: minutes-to-months timescales, single to multiple bursts, and peak flux densities from 0.05 to 1.5 Jy, but none of these had X-ray counterparts. The new VLA low-band system's wide bandpass, covering frequencies from ~250 to 450 MHz, is expected to be ~5 times more sensitive than the narrow-band 330 MHz legacy VLA system. Projections of transient rates are presented based on preliminary results of the current monitoring program, and are compared with rates extrapolated from our program on the legacy VLA. Our current program, with one-tenth the observing time as our previous ones combined, could yield ~1-3x as many new transient detections. The improved statistics from continued monitoring, along with spectral information available from the wide bandpass, will help elucidate the nature of the underlying GCRT population(s). In addition, we report on any activity observed from the 2013-14 G2 gas cloud interaction with Sgr A*, which some models predict will produce enhancements in emission of several Jy's at < 1 GHz frequencies. Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

346.29 – Multi-Wavelength Studies of Inner Galactic Gas Clouds in Clump 2: IGGC 22

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Contributing teams: HIGGS Team

The inner few hundred parsecs of the galaxy are dominated by the Central Molecular Zone (CMZ) containing the densest concentration of gas and dust in the Galaxy, and at the very center of which lies a massive black hole. Farther out from the center, to about 400 parsecs, is the region called Inner Galaxy (IG) whose dynamics are dominated by the gravitational potential of the Galactic Bar. Material that slowly falls from the outer parts of the Galaxy towards the plane encounters

extreme physical conditions. Dust and molecular material form dense massive clouds, the so-called Inner Galactic Gas Clouds (IGGC). We are using Herschel HIFI and PACS [CII], [NII], [OI], [OIII], and high-J CO emission line observations in focused regions near the Galactic Center supplemented by Herschel and Spitzer photometric data and MOPRA molecular line observations. This poster will present the current status of our ongoing analysis to investigate the physical processes underway in the gas knots IGGC 22 in Clump 2.

346.30 – Evidence for a Massive Photon in the Milky Way

David F. Bartlett[1], John P. Cumalat[1]
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This poster presents further evidence of magnetic fields in astronomy. For the two of us the putative agent is a massive photon of mass m=10 ^-25 eV and Compton wavelength lambda = h/mc= 400 pc. In electricity, the difference between this large range and the infinite range of Coulomb's law is generally concealed by the neutrality of matter and is unobservable in either the laboratory or the cosmos. Astronomers can, however, readily look for the magnetic effects of a massive photon using celestial currents. The dominant moments of any confined current distribution are the magnetic dipole and the toroidal dipole. A combination of these two moments produces a long-range field of negative or positive helicity, H=Sign[A dot B]. Solar astronomers are already familiar with helicity. We give evidence in the Milky Way for force-free fields (J parallel to B parallel to A) of definite helicity and wave-length. Candidates include the Central Bar and the region near the Central Black Hole. Refs: [for AAS-222 poster "The Universe has been coasting since Z=50"] and previous posters and publications - http://www-hep.colorado/Cosinusoidal/

346.31 – Describing the Milky Way Galaxy Using the Cosinusoidal Potential

John P. Cumalat[1], David F. Bartlett[1]
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Using the Cosinusoidal Potential as an alternative to the Newtonian Gravitational Potential, one is able to reproduce the flat rotation curves observed in disk galaxies without the introduction of dark matter. One naturally explains the thinness of the disk and the central bulge. Further, the Cosinusoidal Potential can be used to explain the stability of orbits and why some stars orbit around the z-axis in disk galaxies. In addition, the potential generates stronger tidal forces than anticipated in Newtonian gravity. Here we present the long range behavior of the potential and show how it can provide an explanation for the observation of polar ring galaxies.

346.32 – SOFIA/FORCAST Observations of the Luminous Blue Variables in the Galactic Center

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Three Luminous Blue Variables (LBVs) are located in the vicinity of the Quintuplet Cluster in the Galactic Center: the Pistol star, G0.120-0.048, and qF362. We present imaging at 19, 25, 31, and 37 μm of the region containing these three LBVs obtained with SOFIA using FORCAST. We study the similarities and differences between the three LBVs and address the influence of the hot, massive stars in the adjacent Quintuplet Cluster and the local ambient medium in affecting the morphology, composition, and energetics of dust in the nebulae produced from their outflows. We observe the thermal emission from the Pistol nebula, the asymmetric, compressed shell of hot dust surrounding the Pistol star and provide the first detection of thermal emission from the symmetric, hot dust envelope surrounding G0.120-0.048. However, we do not detect any emission from hot dust surrounding qF362. The Pistol and G0.120-0.048 nebulae share an identical size scale of ? 0.7 pc which suggests that they have similar dynamical timescales (? 8000 yrs) assuming similar expansion velocities of ? 90 km/s. The Pistol nebula exhibits a temperature gradient decreasing from north to south with values ranging from 140 - 150 K. The G0.120-0.048 nebula, which is spherically symmetric about the star, exhibits an average dust temperature of ? 100 K. Fits to the spectral energy distribution (SED) of the Pistol nebula with the DustEm Radiative Transfer code indicate that the nebula is composed of separate distributions of large grains (? 500 Å) and small grains (? 10 Å). DustEm model fits to the G0.120-0.048 nebula SED indicate that it contains grains smaller than 500 Å which suggests it may also contain a population of small grains. The models predict that both nebulae have a total gas mass of ? 2.5 M™ (assuming Mg/Md = 100), and a total IR luminosity of ? 8 × 10^5 L™ for the Pistol and ? 10^5 L™ for G0.120-0.048.

346.33 – Gemini GNIRS/NIFS Study of the Radial Velocities of Eight Massive Stars in the Galactic Center

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We present a study of eight massive stars lying within the 10? to the Galactic West of the Arches cluster, using new Gemini GNIRS and NIFS near-infrared spectra. The radial velocities of these stars and nearby HII regions are measured from hydrogen, helium and nitrogen absorption/emission lines. We also derive the ages and masses of our sample from the unreddened color-magnitude diagram (J-K vs K). Compared to the Arches cluster, these stars are blueshifted, by > 50 km/s. Five of the eight stars, especially the two (P35 and P114) within the H1/H2 HII regions, have radial velocities similar to nearby molecular clouds, while the other three stars do not. The velocity gradient of the ionized gas in H1/H2, relative to P35/P114 and the nearby -30-0 km s1 molecular clouds, can be explained by the pressure-driven flow model, but not by a bow shock model. Instead of being interlopers unassociated to the molecular cloud, we argue that P35 and P114 formed in situ, triggered by the interaction between the -30-0 km s1 molecular cloud and the Sgr A* 2 Myr ago, Like the three WNh stars 2 pc away from the Arches cluster, another two stars (P97 and P98, <8 pc, projected distance, away from the Arches cluster) are its previous members, given their proximity and comparable ages to that cluster, but in which case they were likely ejected due to three-body interactions. The three X-ray point sources in the core of the Arches cluster, i.e., the massive binaries, could be the product of these three-body interactions. The origin of the other four stars is not yet clear.

346.34 – The Fermi bubbles: gamma-ray, microwave and polarization signatures of leptonic AGN jets

Hsiang-Yi Karen Yang[1], Mateusz Ruszkowski[1], Ellen G. Zweibel[2]
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The origin of the two large bubbles at the Galactic Centre observed by the Fermi Gamma-ray Space Telescope and the spatially correlated microwave haze emission are yet to be determined. To disentangle different models requires detailed comparisons between theoretical predictions and multiwavelength observations. Our previous simulations, which self-consistently include interactions between cosmic rays (CRs) and magnetic fields, have demonstrated that the primary features of the Fermi bubbles could be successfully reproduced by recent jet activity from the central active galactic nucleus (AGN). In this work, we generate gamma-ray and microwave maps and spectra based on the simulated properties of CRs and magnetic fields in order to examine whether the observed bubble and haze emission could be explained by leptons contained in the AGN jets. We also investigate the model predictions of the polarization properties of the Fermi bubbles, including the polarization fractions and the rotation measures (RMs). We find that (1) the same population of leptons can simultaneously explain the bubble and haze emission given that the magnetic fields within the bubbles are very close to the exponentially distributed ambient field, which can be explained by mixing in of the ambient field followed by turbulent field amplification. (2) The centrally peaked microwave profile suggests CR replenishment, which is consistent with the presence of a more recent second jet event. (3) The bubble interior exhibits a high degree of polarization because of ordered radial magnetic field lines stretched by elongated vortices behind the shocks. (4) Enhancement of RMs could exist within the shock-compressed layer because of increased gas density and more amplified and ordered magnetic fields. We discuss the possibility that the deficient haze emission at b<35 degrees is due to the suppression of magnetic fields, which is consistent with the existence of lower energy CRs causing the polarized emission at 2.3 GHz. Possible AGN jet composition in the leptonic scenario is also discussed.

346.35 – Astrometry in the Galactic Center with the Thirty Meter Telescope

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We report on the expected astrometric performance of the imaging capabilities of the Thirty Meter Telescope's InfraRed Imaging Spectrometer (IRIS), which will be behind a multi-conjugate adaptive optics (AO) system, as determined using simulated images of the Galactic center. This region of the Galaxy harbors a supermassive black hole and a dense nuclear stellar cluster, thus providing an ideal laboratory for testing crowded-field astrometry with the IRIS imager. Accounting for the various sources of astrometric error is important for making precision measurements of the short-period stars orbiting the supermassive black hole in order to probe the curvature of space-time as predicted by General Relativity and to understand the origin of the nuclear star cluster. In the simulated images, which cover a field of view of 17" × 17" (4096 × 4096 pixels), several sources of astrometric error are incorporated, including spatially variable point spread functions, confusion, the static geometric optical distortion from the IRIS imager, and the time-variable distortion introduced by the on-instrument wave front sensor. Because of the higher resolution of the TMT, it will detect stars down to K?24 (?0.1 M_{sun} for main sequence stars), which is ?3 magnitudes fainter than what is seen today with current 8-10 m class telescopes. Optical distortion is the limiting source of error for bright stars (K < 15), while fainter sources will be limited by the effects of source confusion. A detailed astrometric error budget for the Galactic center science case is presented.

347 – Extrasolar Planet Characterization Poster Session

Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

347.01 – A Statistical Analysis of Exoplanets in Their Habitable Zones

Arthur Adams[1], Stephen R. Kane[1]
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The Kepler mission has detected a wealth of planets through planetary transits since its launch in 2009. An important step in the continued study of exoplanets is to characterize planets based on their orbital properties and compositions. As the Kepler mission has progressed the data sensitivity to planetary transits at longer orbital periods has increased. This allows for an enhanced probability of detecting planets which lie in the Habitable Zones (HZs) of their host stars. We present the results of statistical analyses of Kepler planetary candidates to study the percentage of orbital time spent in the HZ as a function of planetary parameters, including planetary mass, radius, and orbital eccentricity. We compare these results to the confirmed exoplanet population.

347.02 – A Statistical Characterization of the Atmospheres of Kepler's Planet Candidates

Holly Sheets[1], Drake Deming[1]
1. University of Maryland, College Park, MD, United States.

We present a method to detect small atmospheric signals in Kepler's planet candidate light curves by transforming and averaging light curves for multiple candidates with similar orbital and physical characteristics. This statistical method greatly increases the signal to noise, allowing for very small signals to be detected. We are looking for reflected light and/or thermal emission at secondary eclipses of planets significantly smaller than hot Jupiters. We detect a secondary eclipse for an average of close-in planets less than 6 Earth radii, consistent with a low average albedo, and we see no eclipse for a control group of similar-sized planets with an expected signal less than 1 ppm for any albedo. We also apply a similar method to search for signatures of light refracted by the planetary atmosphere just outside of transit.

347.03 – Direct modeling of transiting planet light curves from model stellar atmospheres

Joseph Mcneil[1], Hilding Neilson[1], Richard Ignace[1]
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Recent and new observations of extrasolar planets via the transit method are provided unparalleled measurements that enhance our understanding of both the planets and their host stars. However, analysis techniques assume simple parameters to describe the stellar intensity profile. In this work, we compare new planetary transit light curves computed directly from model stellar atmosphere intensity profiles with light curves computed using limb-darkening coefficients. This comparison highlights the need for better models of stellar intensities and atmospheres to better understand the extrasolar planets themselves, especially in the upcoming eras of TESS and PLATO.

347.04 – Gaseous Mean Opacities for Giant Planet and Brown Dwarf Atmospheres

Jacob A. Lustig-Yaeger[1], Jonathan J. Fortney[1], Richard Freedman[2, 3], Mark S. Marley[3], Roxana E. Lupu[2]
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Radiative energy transport is the primary mechanism responsible for the thermal structure of a planetary atmosphere. The study of how radiated energy is captured by an atmosphere fundamentally depends on the opacity of the atoms and molecules present at the temperatures and pressures relevant in these atmospheres. Although atmospheric opacity strongly depends on the frequency of radiation, analytic radiative energy transport solutions require the simplicity of grey atmospheres. Motivated by the broad usage of grey atmospheres, we present tables of Rosseland and Planck mean opacities to the community. Our new mean opacity tables include absorption due to atoms, molecules, and ions, but neglect the opacity due to condensates. We provide opacity tables at local temperatures, as well as with stellar blackbody weighting functions for use in strongly irradiated atmospheres. Tables are provided at metallicities up to 50 times solar, and we show a simple analytic fit to these tables as well.

347.05 – Searching for Extended Planetary Atmospheres Signatures In Kepler Light Curves

Estella Barbosa de Souza[1], Seth Redfield[2], Adam G. Jensen[3]
1. Bryn Mawr College, Bryn Mawr, PA, United States. 2. Wesleyan University, Middletown, CT, United States. 3. University of Nebraska, Lincoln, NE, United States.

The Kepler mission has discovered a rich array of other planetary systems. The prospects for evaluating the habitability around Earth-like planets remains a profound endeavor. Among the several characteristics that make a planet habitable is its atmosphere. The transits extracted from the Kepler database can potentially provide information regarding extended atmospheres and extreme planetary mass loss. Extended atmospheres have been identified in transmission spectroscopy and at least one extreme example has been identified in the Kepler sample. We present a comprehensive survey of the Kepler database to look for promising candidates which show transit anomalies that are consistent with extended planetary atmospheres. Our algorithm fits a standard transit model and evaluates characteristic departures from the fit in order to identify candidates.

347.06 – Tidal Evolution of Exomoons using a Self-Consistent Tidal and Dynamical Model

Rhett Zollinger[1,2], John C. Armstrong[2], Benjamin C. Bromley[1]
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The recent success of Kepler and other planet hunting missions has helped motivate new interest in planet habitability. Now that the detection of massive satellites that orbit extrasolar planets has become feasible, interest in the habitability of exomoons has also emerged. Stellar insulation is commonly used as the main constraint on potential habitability. Exomoon habitability models have also considered additional energy sources such as stellar eclipses by the planet, the planet's thermal emission and its stellar reflected light, as well as tidal heating of the moon. Tidal processes between a moon and its parent planet will determine the orbit and spin evolution of the moon. Gravitational perturbations will also have an effect on the evolution of a moon in a closely packed system with many massive bodies. Such examples include a large moon orbiting a giant planet in the habitable zone of a low mass star or a giant planet with multiple large moons. For resonant systems the evolution equations must be integrated directly to test for instability and to allow for variation of the semimajor axes. Therefore, to further constrain exomoon habitability it is necessary to simulate the orbital evolution of a satellite with a model that considers both gravitational scattering and tidal evolution. We have developed a simulation that uses an efficient method for calculating self-consistently the tidal, spin, and dynamical evolution of a many-body system. The method is based on formulations by Heggie and Eggleton (1998) as well as work by Mardling and Lin (2002). A planet and moon are given extended structure while other bodies are treated as point masses. The tidal evolution as well as the evolution of spin rates and obliquities are calculated for the extended bodies using arbitrary initial conditions. Our results will be presented for theoretical low mass stellar systems as well as hypothetical moons around some recently discovered exoplanets.

347.07 – Chasing Luna: Detecting Exomoons

Megan Lovell[1], Ethan A. Deneault[1]
1. University of Tampa, Tampa, FL, United States.

Exomoons are moons that orbit an extra-solar planet. Exomoons have the potential to be habitable, depending on the location of their host planet in relation to its star. These moons are usually too small to actually see, so the motion of the host planet is used to determine whether or not an exomoon is present. The research I conducted tested the detectability of exomoons. An exoplanet without any known exomoons was used (Kepler 12B). By inserting theoretical exomoons of different radii and distances from the planet, I was able to see how these variables affected their detectability. From this data I was able to investigate optimal distances and radii of exomoons that can be detected using this method.

347.08 – Investigations of Planet Formation with Combined Hydrodynamics and Radiative Transfer

Hannah Jang-Condell[1], Dylan Kloster[1]
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Our aim is to investigate how the dynamics of protoplanetary disks are affected by environmental factors such as the presence of a planetary-mass object orbiting at the midplane and the radiation produced by the disk's host star. To accomplish this task we utilize the finite-volume numerical code PLUTO (Mignone, et al. 2007) to compute the evolution of the disk as a magnetohydrodynamics (MHD) simulation in 3D spherical coordinates, combined with a radiative transfer code (Jang-Condell 2008). At each iteration of the PLUTO simulation we will apply the radiative transfer code to the disk profile to model both processes simultaneously. The combined MHD and radiative transfer simulation will provide us with a much more accurate description of protoplanetary disk evolution than either isolated disk MHD or static disk radiative transfer models could individually.

347.09 – Exoplanent Science with OSCAAR

Taylor Morris[1], Douglas T. Durig[1], Brett M. Morris[2]
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Exoplanets with large magnitude depths often transit bright host stars, allowing Earth-based, photometric measurements of flux over time to be acquired with appropriate techniques on even modest astronomical equipment. OSCAAR (Open Source Code for Accelerating Astronomical Research) is an open-source, Python-based, differential photometry software package designed for gathering and analyzing data on Jupiter to Neptune sized exoplanets. While beta-testing the OSCAAR code, an efficient data-collection system and effective research procedure for transit analysis was developed at the Cordell-Lorenz observatory in Sewanee, TN. Promising transit data was obtained for exoplanets such as WASP-52 b and WASP-59 b. We present the first user-generated exoplanet light curves and Markov Chain Monte Carlo (MCMC) fitting results utilizing OSCAAR and compare them to the currently available orbital parameters. Discussion of the implications of our data, such as a potential shift in the timing of WASP-52 b's transit, is then considered, as well as potential future work.

347.10 – Effects of Roche Lobe Overflow from Eccentric Hot Jupiters Created by Planet-Planet Scattering

Jeremy F. Sepinsky[1], Rachel L. Salmon[1], Sourav Chatterjee[2]
1. University of Scranton, Scranton, PA, United States. 2. The University of Florida, Gainesville, FL, United States.

As the number of extra solar planets and planet candidates increases, so does the number of systems that look strikingly different from our own. In this poster, we explore the creation of close-in eccentric Jupiter-mass planets. We show that planet-planet scattering can create a significant population of hot Jupiters that pass close enough to their parent stars to undergo Roche Lobe overflow (RLOF) at periastron. We investigate the distribution of these eccentric, Roche-Lobe-overfilling planets and study their subsequent orbital evolution. We find that depending on the mass accretion rate and tidal quality factor there are regimes where changes in the orbital properties due to RLOF at periastron is comparable or even higher than to those due to static tides. Our results suggest that RLOF from planets in such eccentric orbits may be a contributing factor in the creation of some long-lived eccentric Hot Jupiters.

347.11 – Earth-like Planet on a Highly Eccentric Orbit: A 1-D Dynamical Model of Atmospheric Response at Periastron

Erica Gonzales[1], Greg Laughlin[1]
1. University of California, Santa Cruz, CA, United States.

The discovery and characterization of extrasolar planets, such as HD 80606b, that have highly eccentric orbits and insolation levels that vary radically over the course of one orbital period, suggests that Earth-mass planets with similar orbits might soon be detected. We use a one-dimensional Courant-limited radiation-hydrodynamical scheme to investigate the time-dependent response of an Earth-like atmospheric column to a periastron passage similar to that experienced by HD 80606b. We use our results to draw potential conclusions regarding the range of weather variations (and ultimately the habitability) of Earth-analogue planets on highly eccentric orbits.

347.12 – Examining Photometric Orbital Modulations in Kepler Transiting Planet Candidates

Tara Fetherolf[1], Avi Shporer[2], Heather Knutson[2], John A. Johnson[3, 2]
1. San Diego State Univesity, San Diego, CA, United States. 2. California Institute of Technology, Pasadena, CA, United States. 3. Harvard University, Cambridge, MA, United States.

Photometric light curves of eclipsing binary stars and star-planet systems reveal important information pertaining to the systems' properties. Most notably, the relative radii of the two components are measured using photometry. The masses traditionally require radial velocities, but telescope time for high resolution spectroscopy is expensive. However, recent studies have shown that masses can be measured from the photometric light curve alone, if sinusoidal modulations are observed at the orbital period of the system. These periodical modulations are known as beaming, ellipsoidal, and reflection effects and are caused by interactions between the two objects. We are using the high quality photometric data taken with the Kepler space telescope and an automated program to extract sinusoidal signals at the known orbital ephemeris, specifically for Kepler transiting planet candidates. While several systems have sinusoidal signals, many are related to stellar activity and/or not necessarily induced by the interaction between the two bodies. We focus on systems with significant orbital modulations caused by the beaming, ellipsoidal, and reflection effects to further understand their nature.

347.13 – Constraining the Magnetic Fields of Transiting Exoplanets through

Ground-based Near-UV Observations

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We observed the primary transits of the exoplanets CoRoT-1b, HAT-P-1b, HAT-P-13b, HAT-P-22b, TrES-2b, TrES-4b, WASP-12b, WASP-33b, WASP-44b, WASP-48b, and WASP77A-b in the near-ultraviolet photometric band in an attempt to detect their magnetic fields and update their planetary parameters. Vidotto et al. (2011) suggest that the magnetic fields of these targets could be constrained if their near-UV light curves show an early ingress compared to their optical light curves, while their egress remain unaffected. We do not observe this effect in any of our targets, however, we have determined an upper limit on their magnetic field strengths. Our results are consistent with observations of TrES-3b and HAT-P-16b which both have had upper limits on their magnetic fields found using this method. We find abnormally low field strengths for all our targets. Due to this result we advocate for follow-up studies on the magnetic fields of all our targets using other detection methods (such as radio emission and magnetic star-planet interactions) and other telescopes capable of achieving a better near-UV cadence to verify our findings and the techniques of Vidotto et al. (2011). We find that the near-UV planetary radii of all our targets are consistent within error of their optical radii. Our data includes the only published near-UV light curves of CoRoT-1b, HAT-P-1b, HAT-P-13b, HAT-P-22b, TrES-2b, TrES-4b, WASP-33b, WASP-44b, WASP-48b, and WASP77A-b. We used an automated reduction pipeline, ExoDRPL, to perform aperture photometry on our data. In addition, we developed a modeling package called EXOMOP that utilizes the Levenberg-Marquardt minimization algorithm to find a least-squares best fit and a differential evolution Markov Chain Monte Carlo algorithm to find the best fit to the light curve. To constrain the red noise in both fitting models we used the residual permutation (rosary bead), time-averaging, and wavelet method.

347.14 – Disentangling the Planetary and Stellar Components of Transit Light Curves

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The difficulty in confirming Kepler planet candidates from the ground drives the creation of more sophisticated transit light curve analyses. These analyses attempt to isolate planetary effects on the light curve and determine important planet properties such as size, mass, albedo, and temperature. The out-of-transit planetary signals can be dominated by seemingly minor stellar effects such as star spots which are not accounted for in the Kepler data pipeline. Fast rotating host stars can cause undulations in the light curve and become entangled with planetary phase effects. We compare two methods to remove these stellar effects. In the first method, we model the stellar star spot signal. The second method requires the filtering out the stellar rotation signal indicated by star spots through Fourier decomposition. We present preliminary results on the effectiveness of these two methods.

347.15 – Chaotic dynamics of the highly inclined planet in HD 196885 AB

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Planetary research has accelerated in the last decade with the confirmation of many exoplanets among which 7% are found to orbit binary stars where depending on the planetary orbit around the host star(s), a planet could orbit either one or both stars as S-Type or P-Type, respectively. Planets within binary systems can be transiting as is the case of the Kepler candidate KOI-284 [Bourcki et al. ApJ 736, 19 2011] or inclined with respect to the binary plane. We study the S-Type system in HD 196885 which illustrates an interesting dynamics due to the higher orbital inclination [Chauvin A&A 528, A8 2011]. We have used the mean exponential growth factor of nearby orbits (MEGNO) maps as an indicator to determine regions of chaos for the various choices of orbital inclination, semi-major axis and longitude of ascending node with respect to the previously determined observational uncertainties. Based on our analysis we have quantitatively mapped chaotic and quasi-periodic regions of the system's phase space which indicate regions of likely stability. In addition, we inspect the resonant angle to determine whether alternation between libration and circulation occurs as a consequence of Kozai oscillations. Also, we demonstrate the possible higher mass limit of the planet and improve upon the current ephemeris with a more consistent dynamical model based on our stability analysis.

347.16 – Near-UV and Optical Observations of the transiting hot Jupiter WASP-1b

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We present simultaneous near-UV (U-band) and optical (B-band) photometric observations of the primary transit of the highly irradiated, hot-Jupiter WASP-1b on the Kuiper 61" telescope. We use our results to search for timing transit variations, which would indicate additional planets, and provide new constraints on WASP-1b's physical parameters. Assuming the opacity at these two photometric bands is dominated by Rayleigh scattering by molecular hydrogen, we can place strong upper limits on its radius. Such constraints can limit the degeneracy between an exoplanet's physical radius and atmospheric composition in radiative transfer retrievals. Additionally its host star is chromospherically active and WASP-1b orbits within in the co-rotation radius of the star making it likely that WASP-1b has a bowshock. Therefore, we will search for a planetary magnetic field as indicated by an early ingress in the near-UV light curve compared to the optical due to the bowshock itself. Such measurements would confirm the observational methodology of detecting magnetic fields around transiting exoplanets, place an upper limit on WASP-1b's magnetic field strength, and confirm previous theoretical estimations of hot Jupiter magnetic fields.

347.17 – Detailed Abundances of Stars with Small Planets Discovered by Kepler

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We present the results of a detailed abundance analysis of three stars with small planets discovered by NASA's Kepler spacecraft. The abundances of 15 elements have been analyzed for possible trends with condensation temperature of the elements, negative or flat trends in which have been previously suggested as possible indicators of terrestrial planet formation. Here we discuss the compositions of stars known to host small planets with the goal of conclusively determining if terrestrial planet formation leaves a detectable signature in the abundance patterns of host stars. This research is supported by a generous grant from NASA as part of the Kepler Participating Scientist Program.

347.18 – Using N_2-N_2 Collisionally-Induced Absorption to Detect N_2 and Determine Pressure in Planetary Atmospheres

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Planetary habitability is determined by the stability of liquid water at the surface, which depends on surface temperature and pressure. While molecular nitrogen (N_2) constitutes the bulk of Earth's atmosphere (~78% by volume) and is the biggest contributor to surface pressure, it is also extremely hard to remotely detect. In particular, N_2 lacks significant absorption features in the visible to near infrared because it is a symmetric homonuclear molecule with no transitional dipole moment. However, nitrogen has a collisionally-induced absorption (CIA) feature near 4.3 μm, nearly coincident with the 4.3 μm CO_2 band but extending to shorter wavelengths. This feature has been known to spectroscopists for some time, but has never been considered in the context of exoplanet characterization from full-disk observations. We report a direct detection of this N_2-N_2 CIA feature in disk-integrated spectra of Earth taken by NASA's EPOXI mission. We use the Virtual Planetary Laboratory's 3D, line-by-line, multiply scattering Earth Model (Robinson et al., 2011) to match the EPOXI spectrum with a synthetic spectrum that includes N_2-N_2 CIA (coefficients from Lafferty et al., 1996). Because N_2 is stable in the atmosphere for geologically long periods and is present in large quantities in the atmospheres of Earth and Venus, it may be a major component of many terrestrial exoplanet atmospheres. Since the strength of a CIA feature goes as the square of the density of the gas, it is more sensitive to pressure than other forms of absorption. We use a self-consistent 1D climate model and a line-by-line radiative transfer model to explore different pressure scenarios from 0.2 to 10 bars assuming pure N_2-CO_2-H_2O atmospheres. We investigate the detectability of N_2 in direct beam and transmission and quantify the signal-to-noise ratio required to distinguish between the different pressure cases. For example, to detect the difference between the 1 and 2 bar models at a 5-sigma level in direct beam observations at 4 μm (?λ=0.05 μm), we find a signal-to noise ratio of 8.1 is required. For planets whose atmospheres contain primarily nitrogen, this is another tool to quantify pressure and, thus, to help constrain planetary habitability.

347.19 – Multiple Scattering in Transit Transmission Spectroscopy

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Exoplanet transit transmission spectroscopy is a powerful tool that has been used to characterize Jupiter and Neptune-sized transiting exoplanets, and a Super-Earth/Mini-Neptune. Because of the flat and featureless spectra for many of these planets, a large number of exoplanets are thought to have cloud or aerosol haze layers in their atmospheres. Clouds and aerosols lead to extinction of flux, but can also scatter photons into the beam to a distant observer. Most transit transmission spectroscopy models include extinction from cloud and aerosol particles, but do not include the effects of directional and multiple scattering from these particles. We have updated an existing transit transmission spectroscopy model to include a backwards Monte Carlo ray tracing scheme that simulates directional and multiple scattering from cloud and aerosol particles. For the paths which connect the host star to a distant observer, we generate a transit transmission spectrum using the calculated paths. We have run simulations for scattering functions ranging from isotropic to strongly forward scattering. We vary the optical depth from optically thin (max transmission of 10% on limb) to very optically thick (max transmission of 0.1%) and the particle vertical distribution from homogeneously distributed in the atmosphere to over a only one layer of the model atmosphere. We find that for a particle layer that is optically thin and confined to a narrow vertical extent, multiple scattering can lead to significant decreases in planetary absorption by nearly 30% when compared to model results with only extinction from clouds and aerosols.

347.20 – PISCES Development and Status: An Integral Field Spectrograph for the High Contrast Imaging Testbed

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We present the development plans and status for PISCES, a visible light (0.4-1 micron) integral field spectrograph (IFS) for NASA's High Contrast Imaging Testbed at the Jet Propulsion Laboratory. PISCES, the prototype imaging spectrograph for coronagraphic exoplanet studies, is a lenslet-based integral field spectrograph (IFS) with a diffraction limited spatial sampling and a spectral resolution of ~70. This prototype IFS will be the first to demonstrate the challenging high contrast instrument requirements to directly detect and characterize habitable exoplanets. PISCES will advance important technologies for the AFTA Coronagraph and the Exo-C Probe.

347.21 – WFC3: Precision Infrared Spectrophotometry with Spatial Scans of HD 189733b and Vega

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Contributing teams: WFC3

The Wide Field Camera 3 (WFC3) on the Hubble Space Telescope (HST) now routinely provides near-infrared spectroscopy of transiting extrasolar planet atmospheres with better than ~50 ppm precision per 0.05-micron resolution bin per transit, for sufficiently bright host stars. Two improvements of WFC3 (the detector) and HST (the spatial scanning technique) have made transiting planet spectra more sensitive and more repeatable than was feasible with NICMOS. In addition, the data analysis is much simpler with WFC3 than with NICMOS. We present time-series spectra of HD 189733b from 1.1 to 1.7 microns in transit and eclipse with fidelity similar to that of the WFC3 transit spectrum of HD 209458b (Deming et al. 2013). In a separate program, we obtained scanned infrared spectra of the bright star, Vega, thereby extending the dynamic range of WFC3 to ~26 magnitudes! Analysis of these data will affect the absolute spectrophotometric calibration of the WFC3, placing it on an SI traceable scale.

347.22 – Day-side Spectrum of the hot-Jupiter WASP-1b

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Ground-based observations have yielded a wealth of new and unexpected information regarding the atmospheric composition and structure of transiting exoplanets. When considered in conjunction with space-based data, we have the potential to form a more complete picture of the atmosphere of an exoplanet. We present a day-side, emission spectrum of the transiting hot-Jupiter WASP-1b. Our spectrum is based on three secondary eclipses obtained using the mid-resolution spectrograph SpeX at the NASA Infrared Telescope Facility (IRTF) (this work) and Spitzer/IRAC observations of two secondary eclipses (Wheatley et al. 2010, draft). We find that our IRTF/SpeX flux densities are notably brighter than the typical brightness temperatures implied by the longer wavelength data. A more coherent picture of the atmosphere of WASP-1b requires additional observations with improved spectral resolution.

347.23 – Modeled Near-Infrared Water Vapor Absorption in a Habitable Super-Earth Orbiting a Late-M Dwarf

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Motivated by recent results demonstrating very high sensitivity for transmission spectroscopy of exoplanets in the 1.1-1.7 micron region using HST/WFC3, we are calculating the sensitivity for measuring water vapor in the atmosphere of a habitable super-Earth orbiting a nearby late-M dwarf star. Such a world is expected to be detected by future surveys, and follow-up transmission spectroscopy may be possible using HST/WFC3 or JWST. Our calculations use a well-tested line-by-line transmission code based on the Partridge and Schwenke line database, as well as Phoenix model atmospheres for the host star. We calculate the sensitivity for the detection in the presence of additional atmospheric opacity such as clouds and haze, as indicated by recent results for both giant exoplanets and super-Earths.

347.24 – How Low Can You Go? The Photoeccentric Effect for Planets of Various Sizes

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It is well-known that the light curve of a transiting planet contains information about the planet's orbital period and size relative to the host star. We can also extract the eccentricity from the light curve because eccentricity changes the transit duration and shape compared to the transit of a planet on a circular orbit. This is one manifestation of what we call "the photoeccentric effect." So far, this approach has only been used to study large planets with high signal-to-noise (S/N) transit data, which raises the question of how well the photoeccentric effect can constrain eccentricities for smaller planets or in cases with lower S/N. We explore the limits of the photoeccentric effect with analytic and numerical techniques. For a set of planetary and stellar parameters we are able to predict the best-case uncertainty in eccentricity that can be measured via the photoeccentric effect. This clears the path to study the precise eccentricities of a larger and more diverse collection of planets in the Kepler sample.

347.25 – Physical Properties of Known Exoplanet and Host Stars Within Ten Parsecs: X-ray/UV Fluxes, Rotation, Ages, and Potential of Habitability

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We have compiled a catalogue of all exoplanets and their host stars within ten parsecs (32.6 ly) from the Sun. In addition to the physical properties of the exoplanets: estimated mass, orbital period, etc; we have compiled the properties of the host stars. These include: spectral class, effective temperature, luminosity, metallicity, period of rotation, etc. For the stars that have X-Ray observations and UV spectrophotometry, we have measured the X-UV irradiances at the distance of the exoplanets orbiting them. In addition, we estimated the ages of the stellar systems using our Rotation-Age-Activity relationship developed at Villanova over the last ten years. These results were used to evaluate the potential habitability of the exoplanets with particular attention is paid to stars with Super-Earth planets orbiting within the habitable zones of their host stars. These include GJ 581, GJ 876, Tau Ceti, and HD 20794. We focus on the GJ 581 system, since it contains at least two Super-Earth exoplanets on the inner and outer boundaries of the habitable zone (GJ 581c and GJ 581d respectively), and because the host star has recently been observed with the SWIFT satellite and detected to be an X-Ray source with a $\log(L_X)\sim26.1$ erg/s (Vitale and France A&A 2013). We also utilized the recently secured FUV-UV HIST/COS spectrophotometry (France et al. ApJ 2013) to compute X-Ray to UV irradiances at GJ 581c and GJ 581d. In addition to the XUV irradiance studies, we have estimated the age of the GJ 581 system from the: rotational period, Lyman Alpha Emission, Mg-II emission, Ca-II emission; using our Rotation-Age-Activity relationship from our Living with a Red Dwarf program. We calculate an average age determination of 7.5±2 Gyr. We discuss how these results affect the relevance of these stars as potential destinations of interstellar travel in the future. We acknowledge the support for this study from NSF/RUI grant

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We observed the primary transits of GJ-1214b and Kelt-1b using the I and R photometric filters on the Kuiper 61" telescope. GJ-1214b is a super earth and Kelt-1b is a hot Jupiter. GJ-1214b has a flat transmission spectrum, which is most likely due to clouds in tis atmosphere. Kelt-1b was the first planet discovered by the KELT survey, and it also has a brown dwarf companion. Because of this, we can expect to observe a timing transit variation. A major component of this project is to give students a learning experience beyond the classroom by getting them involved in an introductory astronomy project. Undergraduates have the opportunity to gain hands-on experience doing data reduction and analysis while still being able to contribute updated planetary parameters for both these systems.

347.30 – The Impact of Stellar Multiplicity on Planet Occurrence

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The majority of searches for extrasolar planets have concentrated exclusively on single stars, actively avoiding close binary systems where the companion might complicate the observations and data analysis. However, the majority of solar-type stars are found in binary systems. These binary companions should exert a strong dynamical influence on any planetary system, and hence this systematic bias leaves out knowledge of planet formation fundamentally incomplete. We will present the ongoing results of a high-resolution imaging survey to identify binary companions among a volume-limited sample of 600 Kepler planet hosts within 500 parsecs. This survey exploits nonredundant aperture-mask interferometry (NRM) to super-resolve binary companions down to 1/4 of the diffraction limit (15 mas; <5 AU at 300 pc), identifying the dynamically significant binary companions that are missed by standard imaging surveys. Our results show that binarity does indeed have a profound influence on planet occurrence, suppressing the planet frequency by a factor of ?4 in 5-50 AU binaries. However, unexpected trends for planet survival also are starting to emerge.

347.31 – Effect of Initial Stellar Metallicity on the Evolution of the Habitable Zone and the Search for Life

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During the course of stellar evolution, the location and width of the habitable zone changes as the luminosity and radius of the star evolves. The duration of habitability for a planet located at a given distance from a star is greatly affected by the characteristics of the host star. A quantification of these effects can be used observationally in the search for life around nearby stars. The longer the duration of habitability, the more likely it is that life has evolved. The preparation of observational techniques aimed at detecting life would benefit from the scientific requirements deduced from the evolution of the habitable zone. We present a study of the evolution of the habitable zone around stars of 1.0, 1.5, and 2.0 Msun for metallicities ranging from Z= 0.0001 to Z= 0.070.We also consider the evolution of the habitable zone from the pre-main sequence until the asymptotic giant branch is reached. We find that metallicity strongly affects the duration of the habitable zone for a planet as well as the distance from the host star where the duration is maximized. For a 1.0 Msun star with near solar metallicity, Z = 0.017, the duration of the habitable zone is > 10 Gyr at distances 1.2–2.0AU from the star, whereas the duration is > 20 Gyr for high-metallicity stars (Z = 0.070) at distances of 0.7–1.8AU, and ? 4 Gyr at distances of 1.8–3.3AU for low-metallicity stars (Z = 0.0001). Corresponding results have been obtained for stars of 1.5 and 2.0 solar masses. We discuss the implications of these results from the standpoint of the evolution of life.

347.32 – Reducing Radius and Temperature Uncertainties for Low-Mass Kepler Objects of Interest With Proxy Stars

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The number of exoplanets known to exist around low-mass stars is rising steadily, and we now know that these stars are the most likely to host small planets. The opportunities for the characterization of small planets (and eventually the search for biomarkers in their atmospheres) are bolstered for those that orbit small stars. The small size of their host star boosts the detectability of exoplanetary signatures, from their transit depths to their radial velocity amplitudes. The next generation of telescopes such as JWST and TESS will be well-poised to conduct such studies, but maximizing their return depends crucially upon understanding the population of planets identified around low-mass stars within the existing Kepler sample. Unfortunately, the empirical metrics and synthetic spectra that allow for the characterization of cooler and hotter spectral

types, respectively, breaks down for stars in the spectral range between M1 and K5, making it difficult to determine which exoplanets are the best ones to study more closely with future instruments. Since the vast majority of exoplanets are discovered and characterized by the effect they produce on their host stars, these uncertainties in stellar parameters result in large uncertainties for the radii and temperatures of its planets. We describe our program to reduce these uncertainties for a sample of planet candidates discovered by the Kepler Space Telescope by applying the radii and temperatures of nearby "proxy" stars, which have had their radii measured directly with interferometry, to our target stars. We use spectral typing software to identify suitable proxy stars. We show that by applying the parameters of proxy stars to our target stars, the uncertainties in stellar temperature and radius can be reduced. Finally, we validate our findings by comparing them with the size, temperature, and metallicity determined from near-infrared spectra of our target stars.

347.33 – Quantifying the Effect of Stellar Binaries on the Formation and Evolution of Planetary Systems

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We are conducting a Doppler Survey at Keck combined with NIRC2 K-band AO imaging to search for massive, long period companions to a sample of 148 exoplanet systems detected using the radial velocity method. While large surveys such as this one have made it possible to understand the statistical properties of exoplanet populations, recent studies have focused on determining mass distributions and occurrence rates of planets around individual FGK stars. The goal of this project is to understand how the multiplicity and orbital architecture of planetary systems vary depending on whether these planets are in single, binary, or multiple star systems. By studying the differences between these planet populations, we can determine the effect that stellar companions have on planet formation and evolution. Here we present preliminary results from our radial velocity trend search for massive, distant companions in these systems.

347.34 – X-ray and Hubble/COS UV Measures of Kapteyn's Star: A Crucial Proxy of X-UV Irradiances for Old Red Dwarf Stars that May Host Habitable Zone Planets

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Red dwarfs (dM) stars make up over 80% of the local stellar population and a significant fraction of them are old (age > 4 Gyr). Because of the high frequency of red dwarfs and their longevity, there is a greater possibility of more advanced life in red dwarf planet systems. MEarths, UVES, SDSS-III, and the upcoming TESS mission are some surveys that are targeting these objects. As part of Villanova's Living with a Red Dwarf program, we have obtained HST/COS spectra and Chandra X-ray observations of Kapteyn's star (M1V, V = 8.853, d = 12.76 +/- 0.05 ly, P_rot = 195 days). This star is crucial to the study of old red dwarfs as it is the nearest halo star with a radial velocity of +245.2 km/s and an estimated age of 10-12 Gyr. In our program, Kapteyn's star is the oldest red dwarf and as such serves as an anchor for our age, rotation, and activity relations. The spectra obtained from HST/COS provide one of the cleanest measurements of Lyman-alpha emission for red dwarfs. This is due to Doppler shift from the high radial velocity, separating the Lyman-alpha line from emission produced by the ISM and geocoronal sources. These observations further provide calibration at the old age/low rotation/low activity extremes for our relations. They also provide insights into the magnetic properties as investigating coronal x-ray and UV emission in very old, slowly rotating dM stars. Kapteyn's star also serves as a proxy for metal-poor old disk/Pop II M dwarfs by providing information about X-UV emissions. This information is crucial for determining X-UV irradiances of possible habitable zone planets hosted by old red dwarfs. We gratefully acknowledge the support from NSF/RUI Grant AST-1009903, NASA/Chandra Grants GO1-12124X and GO2-13020X, and HST-GO-13020.

347.35 – Chemistry in an Evolving Protoplanetary Disk: Implications for Carbon Rich Systems

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We model the formation of terrestrial planets with a coupled chemical and dynamical model and use this to predict the compositions of planets that form in carbon rich protoplanetary disks. Our model incorporates the evolution of the disk over time in order to account for change in disk composition throughout the period of time during which planetesimals are forming. We find that in our time evolving model, carbon rich planets are formed throughout a larger radial extent of carbon rich disks than in a static model. We also find that carbon rich planetesimals can form in disks that are not initially enriched in carbon (C/O<0.8) due to the depletion of oxygen by planetesimal formation farther out in the disk.

347.36 – vis.SME -- Building a Visualization Tool to Analyze and Share Spectral Synthesis Stellar Characterization

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New ways of conducting research in observational and computational astronomy has led to a new focus: Big Data Astronomy. With ongoing and planned large-scale surveys including Kepler, K2, Gaia, and TESS, the field of exoplanet detection and characterization has been revolutionized by vast amounts of data leading to the confirmation of over 700 extra-solar planets. However, there continues to be a great need for innovation in data visualization and data-sharing applications to manage the science output within these large collaborations. Motivated by this, we are developing vis.SME, a new tool to visualize stellar characterization outputs from SME@XSEDE -- a recently developed spectral synthesis software that can efficiently determine temperatures, abundances, surface gravities, and rotation rates for hundreds of stars at a time. vis.SME is a web-based tool allowing optimal visualization of stellar characterization results, integration and comparison with other extant data sources, and serve as an effective way for sharing these results between collaboration members. We will present a preview of this new tool, including snapshots of its components and an example of how we are utilizing it to characterize potential Kepler exoplanet hosting stars.

347.37 – False Positives for Life: Atmospheric Ozone and Oxygen on Lifeless Rocky Exoplents

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Oxygen (O_2) and Ozone (O_3) are two of the more commonly-cited biosignature gases for future life-detection and planet characterization missions. In this presentation, we discuss the possibility for abiotic processes to produce these gases and examine the chemical and stellar contexts for these processes. Specifying these contexts and their observables will lead to a discussion on how false positives can be discriminated from true positives, and what the implications are for the capabilities of future exoplanet characterization missions.

347.38 – Hα Absorption During Hot Jupiter Transits

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While Lyman-alpha absorption provides a probe of the hydrogen content of an exoplanet atmosphere, the recent observation of H-alpha absorption by the atmosphere of HD189733b provides an opportunity to probe the thermal structure of the atomic hydrogen. With this in mind, the relative importance of the various creation and destruction pathways for n=2 hydrogen -- collisional excitation, photoionization, radiative recombination, as well as radiative transitions -- are discussed and a present a spherically-symmetric, hydrostatic model of the atmosphere of HD189733b capable of reproducing the observed absorption signal. We build on this work and show preliminary results from two-dimensional simulations of the upper atmosphere which capture the variation in n=2 hydrogen between the day-side and night-side of the planet.

347.39 – A Comprehensive Study of Kepler Phase Curves and Secondary Eclipses

Emily DeLarme[1], Daniel Angerhausen[1], Jon A. Morse[1]
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We present the initial results of a comprehensive study of 318 Kepler Objects of Interest (KOI) with $R\_p > 4 R\_e$, P < 10d, and V_mag < 15 using all 15 quarters of lightcurve data in the latest Kepler data release. Our analysis quantifies system-level effects from ellipsoidal, Doppler beaming and phase-curve variations, and also characterizes the secondary eclipses. This presentation focuses on 19 confirmed planets from this sample: We were able to confirm and improve the temperatures and albedos for Kepler-1b, 2b, 4b, 5b, 6b, 7b, 8b, 12b , 13b, 17b, and 41b, and present new results for Kepler-3b, 14b, 15b, 18c, 40b, 43b, 44b, and 74b. In addition, we used the same methods to analyze the rocky planets Kepler-10b, 78b, and KOI 1843.03.

347.40 – An Analysis of Occultations and Phase Curves of Different KOIs

Jessica Roberts[1], Jason Rowe[2], Elisa V. Quintana[2], Thomas Barclay[2], Natalie M. Batalha[1, 2]
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Occultations and phase curves allow us to characterize atmopsheres of transiting exoplanets. We observe these signals in the light curves of several Kepler Objects of Interest (KOIs). Using sixteen quarters of data from the Kepler spacecraft, we determine the planetary effective temperature and geometric albedo for a sample of planetary candidates. We investigate the possibility of asymmetries (or lack therefor) in the phase curves which may provide information about atmospheric dynamics. We highlight the Kepler-10b and Kepler-41b light curves which both present statistically significant phase curve asymmetries.

348 – Extrasolar Planet Detection
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

348.01 – Improving the RV Precision of HET/HRS - The Tale of Two Iodine Atlases

Sharon Xuesong Wang[1], Jason Wright[1], Ming Zhao[1]
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The absorption spectrum of an Iodine cell provided by a Fourier Transform Spectrometer (FTS) is considered the 'ground' truth in precise radial velocity (RV) work. Modeling the observed Iodine lines with the FTS scan spectrum anchors the absolute wavelength solution and spectrograph response function when extracting RVs from the stellar spectrum. As we continue our efforts in improving the RV precision of the Hobby-Eberly Telescope (HET) High Resolution Spectrograph (HRS), we discovered that errors and uncertainties associated with the FTS scan may comprise the RV precision. We have two FTS scans for the HET/HRS cell from two different FTS machines - from KPNO and NIST. The two scans differ in terms of absolute wavelength solution, wavelength dispersion scale, line depth, and line depth ratio. These two FTS scans provide us with an unusual and valuable opportunity to diagnose the effect on RV precision brought in by the Iodine FTS scan uncertainties. Furthermore, to diagnose the KPNO FTS scan quality, we obtained a R~400,000 echelle spectrum (at a comparable resolution with the FTS scan) of the McDonald 2.7m telescope Iodine cell using the Tull Spectrograph, and compared it against the FTS scan of this cell. There are clear differences between the two spectra, which reveals the difficulties in obtaining the 'ground truth' Iodine spectrum in the precise RV work.

348.02 – Investigating Systematic Errors in Iodine Cell Radial Velocity Measurements

Andrew Vanderburg[1], Geoffrey W. Marcy[2], John A. Johnson[1]
1. Harvard University, Cambridge, MA, United States. 2. University of California, Berkeley, Berkeley, CA, United States.

Astronomers have made precise stellar radial velocity measurements using an iodine cell as a calibrator since the 1980s. These measurements have led to the discovery of hundreds of extrasolar planets, and have contributed to the characterization of many more. The precision of these measurements is limited by systematic errors caused primarily by the instability of the spectrographs used to acquire data, and which are not properly modeled in the data analysis process. We present an investigation of ways to mitigate and better model these systematic effects in data analysis. Such an improvement in the radial velocity analysis process would be readily applicable to twenty years worth of radial velocity data.

348.03 – Minerva exoplanet detection sensitivity from simulated observations

Nate McCrady[1], Chantanelle Nava[1]
1. University of Montana, Missoula, MT, United States.

Small rocky planets induce radial velocity signals that are difficult to detect in the presence of stellar noise sources of comparable or larger amplitude. Minerva is a dedicated, robotic observatory that will attain 1 meter per second precision to detect these rocky planets in the habitable zone around nearby stars. We present results of an ongoing project investigating Minerva's planet detection sensitivity as a function of observational cadence, planet mass, and orbital parameters (period, eccentricity, and argument of periastron). Radial velocity data is simulated with realistic observing cadence, accounting for weather patterns at Mt. Hopkins, Arizona. Instrumental and stellar noise are added to the simulated observations, including effects of oscillation, jitter, starspots and rotation. We extract orbital parameters from the simulated RV data using the RVLIN code. A Monte Carlo analysis is used to explore the parameter space and evaluate planet detection completeness. Our results will inform the Minerva observing strategy by providing a quantitative measure of planet detection sensitivity as a function of orbital parameters and cadence.

348.04 – Update on the SDSS-III MARVELS data pipeline development

Rui Li[1], Jian Ge[1], Neil B. Thomas[1], Eric Petersen[1], Ji Wang[2, 1], Bo Ma[1], Sirinrat Sithajan[1], Jiangli Shi[3], Yuyuan Ouyang[3], Yunmei Chen[3]
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MARVELS (Multi-object APO Radial Velocity Exoplanet Large-area Survey), as one of the four surveys in the SDSS-III program, has monitored over 3,300 stars during 2008-2012, with each being visited an average of 26 times over a 2-year window. Although the early data pipeline was able to detect over 20 brown dwarf candidates and several hundreds of binaries, no giant planet candidates have been reliably identified due to its large systematic errors. Learning from past data

pipeline lessons, we re-designed the entire pipeline to handle various types of systematic effects caused by the instrument (such as trace, slant, distortion, drifts and dispersion) and observation condition changes (such as illumination profile and continuum). We also introduced several advanced methods to precisely extract the RV signals. To date, we have achieved a long term RMS RV measurement error of 14 m/s for HIP-14810 (one of our reference stars) after removal of the known planet signal based on previous HIRES RV measurement. This new 1-D data pipeline has been used to robustly identify four giant planet candidates within the small fraction of the survey data that has been processed (Thomas et al. this meeting). The team is currently working hard to optimize the pipeline, especially the 2-D interference-fringe RV extraction, where early results show a 1.5 times improvement over the 1-D data pipeline. We are quickly approaching the survey baseline performance requirement of 10-35 m/s RMS for V~8-12 solar type stars. With this fine-tuned pipeline and the soon to be processed plates of data, we expect to discover many more giant planet candidates and make a large statistical impact to the exoplanet study.

348.05 – Exploring Exoplanets Out to the Snowline with LCOGT

Rachel Street[1]
1. Las Cumbres Global Telescope Network, Inc., Goleta, CA, United States.
Contributing teams: RoboNet

Microlensing is the most efficient technique for the discovery of cool exoplanets between ~2-10 AU from their host stars, and unique in its capacity to detect and characterize objects down to even lunar masses from ground based observations. The field of microlensing is now reaching maturity, with wider field surveys identifying ~2000 events and ~10 planetary systems per year. Continuous, high precision and high cadence photometry is required over many days spanning the peak of an event to ensure the detection of the subtle anomalies caused by terrestrial companions to the lensing star. Until now this has been achieved with a diverse collection of telescope apertures, worldwide. Here we report on the first season of microlensing observations with a new observing facility ideal for this science: the LCOGT 1m network. During 2012-2013, LCOGT deployed 11 x 1m telescopes to 5 sites around the world in both hemispheres, with the majority of the telescopes going to sites in Chile, South Africa and Australia. These homogenous facilities have now completed their first commissioning season of microlensing observations, demonstrating their capability to find and characterize cool terrestrial planets.

348.06 – Gravitational Microlensing Observations of Two New Exoplanets Using the Deep Impact High Resolution Instrument

Richard K. Barry[1], David P. Bennett[2], Kenneth Klaasen[4], Andrew C. Becker[1], Jessie Christiansen[4], Michael Albrow[3]
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We have worked to characterize two exoplanets newly detected from the ground: OGLE-2012-BLG-0406 and OGLE-2012-BLG-0838, using microlensing observations of the Galactic Bulge recently obtained by NASA's Deep Impact (DI) spacecraft, in combination with ground data. These observations of the crowded Bulge fields from Earth and from an observatory at a distance of ~1 AU have permitted the extraction of a microlensing parallax signature – critical for breaking exoplanet model degeneracies. For this effort, we used DI's High Resolution Instrument, launched with a permanent defocus aberration due to an error in cryogenic testing. We show how the effects of a very large, chromatic PSF can be reduced in differencing photometry. We also compare two approaches to differencing photometry – one of which employs the Bramich algorithm and another using the Fruchter & Hook drizzle algorithm.

348.07 – Transiting Exoplanet Observations at Grinnell College

Julia Sauerhaft[1], Patrick Slough[1], Bryson Cale[1], Eliza Kempton[1]
1. Grinnell College, Grinnell, IA, United States.

Grinnell College, a small liberal arts college in Grinnell, Iowa with 1600 undergraduate students, is home to the Grant O. Gale Observatory. Over the past year, we have successfully detected extrasolar planets using the transit method with our 24-inch Cassegrain reflecting telescope equipped with a CCD camera. With little light pollution and an easily accessible observatory, Grinnell College is an optimal location for transiting exoplanet observations. With the current telescope set-up and CCD camera, we have taken time series data and created image calibration and post-processing programs that detect exoplanet transits at high photometric precision. In the future, we will continue to use these observation and data reduction procedures to conduct transiting exoplanet research. Goals for our research program include performing follow-up observations of transiting exoplanet candidates to confirm their planetary nature, searching for additional exoplanets in known planetary systems using the transit timing detection method, tracking long period transiting planets, and refining properties of exoplanets and their host stars. Ground-based transiting planet science is especially important in the post-Kepler era, and our dedicated mid-sized telescope with plenty of access to dark clear nights provides an ideal resource for a variety of follow up and exoplanet detection efforts.

348.08 – Detection of an Extrasolar Planet Candidate in Habitable Zone of a Low-Mass Binary

Sophie Ponte[1,2], John J. Bochanski[2], Beth Willman[2], Edward F. Guinan[3], Scott G. Engle[3], Nicholas M. Law[4], Christoph Baranec[5], Reed L. Riddle[6]
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We present an analysis of 58 low-mass stars surveyed by the Kepler Space Telescope. Our initial study was a search for eclipses in a sample of candidate M dwarf – white dwarf binary stars. The stars were observed in the Kepler wide-band visual filter nearly continuously over 300 days, at a cadence of 29.5 minutes. The resulting light curves were used to measure the rotation periods for each star in our sample, and identified other transient features, such as flares. The typical signal-to-noise ratio in our sample is 500 or more. During the course of our investigation, one star exhibited signs of a periodic transit. We observed a 1.2% transit signal occurring every 76 days, suggesting a planetary companion with an orbital semi-major axis of ~ 0.3 AU. We have obtained follow-up observations of the host star, including ground-based adaptive optics imaging and spectroscopy. We detail our efforts to characterize the planetary candidate and host star. We gratefully acknowledge the support NSF grant AST-1151462.

348.09 – Project PANOPTES: Crowdsourcing the Search for Exoplanets

Chad Stump[1]
1. Shawnee State University, Portsmouth, OH, United States.

Since the first exoplanets were discovered twenty years ago, nearly 1,000 have been confirmed. Over a third of these were found with the transit method, which holds the promise of more wide-scale searches. If Earth is in their orbital plane, exoplanets will partially eclipse their parent star. The transit method looks for this dimming to measure the size and orbit of the planet. Project PANOPTES is a crowdsourced search for new exoplanets using hobbyist digital cameras, keeping the cost low to make the search broadly accessible. We present information from our attempts to use a Canon EOS Rebel T4i DSLR camera with a Rokinon 85mm aspherical lens to detect transits, and we evaluate the feasibility of building a PANOPTES observatory in Southern Ohio.

348.10 – Planet Hunters: Two New Confirmed Planets and the First <i>Kepler</i> Seven Candidate System

Joseph Schmitt[1], Ji Wang[1], Kian Jek[2], Debra Fischer[1], Eric Agol[3]
1. Yale University, New Haven, CT, United States. 2. Planet Hunters, San Francisco, CA, United States. 3. University of Washington, Seattle, WA, United States.
Contributing teams: Planet Hunters

Planet Hunters has confirmed two new planets, PH3 b and PH3 c, through transit timing variations (TTVs) and discovered a seventh planet candidate KOI-351.07, marking the first *Kepler* seven candidate system. Since most *Kepler* multiple planet candidates are true planets, KOI-351.07 is the strongest proposed seventh planet candidate in any planetary system. KOI-351 is a very compact system; all candidates have periods < 1 year. . Although errors are large, the inner five planets appear to all be sub-Neptune, while the outer two are likely gas giants. In our new confirmed system PH3, both confirmed planets experience significant TTVs, with PH3 b having an amplitude of over 5 hours. Along with the third candidate in the system (KOI-1353.02), this system may be in a Laplace resonance: $P_{out}/P_{mid} = P_{mid}/P_{in} = 1.91$. These new discoveries add to Planet Hunters previous successes: two previously confirmed planets and ? 60 other planet candidates.

348.11 – Progress Toward Reliable Planet Occurrence Rates with Kepler

Natalie M. Batalha[1]
1. NASA Ames Research Center, Moffett Field, CA, United States.
Contributing teams: Kepler Team

The Kepler Mission is exploring the diversity of planets and planetary systems. Its legacy will be a catalog of discoveries sufficient for computing planet occurrence rates as a funtion size, orbital period, star-type, and insolation flux. The mission has gone a long way toward achieving that goal. This year, the number of planet discoveries has increased by 50%, and the number of small planet candidates in the habitable zone has nearly doubled. Statistical analyses suggest that planets abound in the galaxy (with each main sequence star having at least one) and that small planets form efficiently. I will describe the ingredients necessary for determining the occurence rates of planets and report on the progress Kepler has made toward a

reliable determination of eta-Earth. This singular number is arguably Kepler's most important contribution to the future of NASA's exoplanet exploration and the search for life beyond Earth.

348.12 – A TTV-fueled study of non-resonant companions to multiple-transiting systems in the Kepler sample

Juliette Becker[1], Benjamin Montet[1], Jonathan Swift[1], John A. Johnson[2]
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The high precision, continuous time coverage and long baseline of the Kepler mission have allowed for the first analyses of transit timing variations (TTVs) induced by dynamical interactions between planets. Nearly all previous TTV studies have focused on the detection, characterization, and validation of planetary systems in near-resonant configurations. Transit timing data also contains potentially useful information about the existence of massive, non-resonant companions. We have begun a new study to search for such companions. Here, we present preliminary results from our analysis of the first 16 quarters of Kepler data and discuss the implications for the presence of massive, non-transiting companions in these systems.

348.13 – A focal plane mask for the PIAA Complex Mask Coronagraph

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The Phase Induced Amplitude Apodization Complex Mask Coronagraph (PIAACMC) can provide 50% throughput at 0.64 λ/D and nearly 100% throughput at large angular separations with total on-axis starlight extinction. These performance characteristics are close to the fundamental physical limit for any instrument. PIAACMC operates by applying a ? phase shift to a portion of the on-axis starlight using a partially transmissive phase shifting focal plane mask. Design of the mask poses several challenges, especially to provide an achromatic phase shift over a large observational bandwidth. We discuss the design of the PIAACMC focal plane mask in monochromatic light, an optimization procedure for broadband, and considerations for fabrication limits.

348.14 – Gemini Planet Imager Data Analysis Methods, Software, and First Data Release

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Contributing teams: The Gemini Planet Imager instrument and science teams

The Gemini Planet Imager (GPI) is a next-generation adaptive optics coronagraph for direct imaging and spectroscopy of warm self-luminous extrasolar planets, designed to be an order of magnitude more sensitive than existing high-contrast imaging capabilities. GPI has completed laboratory integration and testing, been shipped to Gemini South, and scheduled for first light in November 2013. We describe the calibration and data analyses methods for GPI's integral field spectrograph that observes the high contrast field, and present the results of initial testing at Gemini. We are now delivering to the community both raw and reduced data products for a subset of initial observations, plus the open-source data analysis pipeline developed by our team.

348.15 – Non-Redundant Masking Science on the Gemini Planet Imager

Alexandra Greenbaum[1], Anand Sivaramakrishnan[2], Laurent Pueyo[2], Schuyler Wolff[1], Marshall D. Perrin[2], Patrick Ingraham[3], Sandrine Thomas[4], Barnaby Norris[5], Peter Tuthill[5]
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Non-Redundant Mask Interferometry (NRM) transforms a fully transmissive pupil into an interferometer by masking all but a set of holes that form unique baselines. The interferometric resolution and dynamic range makes the technique suitable for probing potential planet forming regions. So called "transition disks" may or may not have perturbing bodies in the process of changing the disk morphology (cleared gaps, etc.) and require close-in imaging to peer inside disk clearings and spot companions that are several orders of magnitude fainter than the host star. Improvements in contrast for NRM rely on both the wavefront quality as well as the data reduction methods. Image plane modeling of the NRM point-spread function avoids ringing and windowing effects that result in Fourier domain analysis of bad pixel and restricted field of view data. The Gemini Planet Imager (GPI), an extreme adaptive optics system and integral field spectrograph, is equipped with a 10-hole NRM. We

present recent results from GPI NRM I&T data using the image plane approach to measure visibilities as an early prediction of performance. We additionally discuss the feasibility of measuring visibility amplitudes from ground-based studies and their implications for NRM science with GPI.

348.16 – Archival Legacy Investigation of Circumstellar Environments (ALICE). Candidates point sources and high-level science products

Choquet Elodie[1], Christine Chen[1], John H. Debes[1], David A. Golimowski[1], J. Brendan Hagan[1, 2], Dean C. Hines[1], Sean Lonsdale[1], Christian Marois[7], Dimitri Mawet[6], Tushar Mittal[5], Margaret Moerchen[1], Mamadou N'Diaye[1], Marshall D. Perrin[1], Laurent Pueyo[1], Abhijith Rajan[3], Iain N. Reid[1], Glenn Schneider[4], Schuyler Wolff[1], Remi Soummer[1]
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The Archival Legacy Investigation of Circumstellar Environments (ALICE) project (HST/AR program 12652; PI Soummer) is currently conducting a comprehensive and consistent reprocessing of HST-NICMOS coronagraphic survey data to search for point sources and disks using advanced PSF subtraction. The Karhunen-Loeve Image Projection (KLIP) algorithm based on principal component analysis was developed for this project. We present the main concept for the pipeline, reduction strategy, and PSF subtraction implementation and performance. The ALICE pipeline was designed to process automatically approximately 400 targets in the NICMOS coronagraphic archive, and to deliver High-Level Science Products (HLSPs) back to the MAST archive at STScI. The HLSPs are defined in collaboration with other similar projects to define a standard format for high-contrast imaging. We present and discuss the ALICE point source candidates detected in the NICMOS archive together with a statistical analysis of the population of background objects.

348.17 – LEECH: Hunting for Planets with LBTI-LMIRcam

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Contributing teams: LEECH Survey Team

In Spring 2013, the LEECH (LBTI Exozodi Exoplanet Common Hunt) survey began its 100-night campaign from the Large Binocular Telescope (LBT) atop Mt Graham, Arizona. This survey benefits from the many technological achievements of the LBT, including two 8.4-meter mirrors on a single fixed mount, dual adaptive secondary mirrors for high Strehl performance, and a cold beam combiner to dramatically reducing the telescope's overall background emissivity. LEECH neatly complements other high-contrast planet imaging efforts by observing stars at L′ (3.8 microns) with LMIRcam, as opposed to the shorter wavelength near-infrared bands (1-2.4 microns) of other similar surveys. This portion of the spectrum offers deeper mass sensitivity for intermediate age (several hundred Myr-old) systems, since their Jovian-mass planets radiate predominantly in the mid-infrared. The goals of LEECH are to (1) discover new exoplanets, (2) characterize the atmospheres of newly discovered exoplanets, (3) characterize the architectures of nearby planetary systems, and (4) establish meaningful constraints on the prevalence of wide-separation exoplanets.

348.18 – High Resolution Active Optics Observations from the Kepler Follow-up Observation Program

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The ground based follow-up observation program for candidate exoplanets discovered with the Kepler observatory has supported a major effort for high resolution imaging of candidate host stars using adaptive optics wave-front correction (AO), speckle imaging and lucky imaging. These images allow examination of the sky as close as a few tenths of an arcsecond from the host stars to detect background objects that might be the source of the Kepler transit signal instead of the host star. This poster reports on the imaging done with AO cameras on the Keck, Palomar 5m and Shane 3m (Lick Observatory) which have been used to obtain high resolution images of over 500 Kepler Object of Interest (KOI) exoplanet candidate host stars. All observations were made at near infrared wavelengths in the J, H and K bands, mostly using the host target star as the AO guide star. Details of the sensitivity to background objects actually attained by these observations and the number of background objects discovered are presented. Implications to the false positive rate of the Kepler candidates are discussed.

348.19 – A Unified Analysis of Brown Dwarf and Exoplanet Companions from Direct Imaging Surveys

Eric L. Nielsen[1], Michael C. Liu[1], Zahed Wahhaj[2], Beth Biller[3], Thomas Hayward[4], Laird M. Close[5], Christ Ftaclas[1], Mark R. Chun[1], Douglas Toomey[6]
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Contributing teams: The Gemini NICI Planet-Finding Campaign Team

While brown dwarfs and exoplanets are currently distinguished by the deuterium-burning limit, the observed distribution of substellar companions over the full range of masses (~1-75 M_Jup) is a promising path to understanding the origin of these objects. To this end, we present a unified analysis of the populations of brown dwarf and exoplanet companions, based on the results from several large-scale direct imaging surveys conducted with high-contrast imaging on 8-10 meter class telescopes. Altogether, these surveys have obtained high-contrast imaging of several hundred stars, spanning a wide range of stellar spectral types (BAFGKM) and age. To account for inhomogeneities in the surveys (including contrast and FOV) and the uncertain properties of the target stars and detected substellar companions, we have developed a new Bayesian framework melded with detailed Monte Carlo simulations in order to measure the frequency of substellar objects, the distributions that describe their masses and semi-major axes, and the associated covariances. Through such a unified analysis, we are able to for the first time examine the interplay between brown dwarf and giant planet populations orbiting nearby stars.

348.20 – iLocater: A Diffraction-Limited Doppler Spectrometer for the Large Binocular Telescope

Justin R. Crepp[1], Andrew Bechter[1], Eric Bechter[1], Michelle Berg[2], Jay Carroll[1], Keegan Collins[1], Taylor Corpuz[1], Ryan Ketterer[1], Edward Kielb[1], Robert Stoddard[1], Joshua A. Eisner[4], B. S. Gaudi[3], Philip Hinz[4], Kaitlin M. Kratter[4], Giusi Macela[5], Andreas Quirrenbach[6], Michael F. Skrutskie[7], Alessandro Sozzetti[5], Charles E. Woodward[8], Bo Zhao[9]
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We are building an ultra-precise Doppler spectrometer for the Large Binocular Telescope (LBT) that operates at near-infrared wavelengths. The instrument, named iLocater, holds significant advantages over current and forth-coming Doppler designs. An R=110,000 spectrograph that operates in the Y-band, iLocater will receive a well-corrected beam from the LBT "extreme" adaptive optics system and use single-mode optical fibers to stabilize the instrument line spread function. With an input image 30 times smaller than comparable seeing-limited instruments (i.e., all Doppler radial velocity predecessors), iLocater will simultaneously achieve high spectral resolution, high spatial resolution, high throughput, and a compact optical design for low cost (affordable gratings). By working at the diffraction-limit, it is possible to circumvent, or ameliorate, many of the sources of noise common to seeing-limited spectrometers, including background contamination, thermal drifts, binary star interlopers, and pressure-induced changes in refractive index. Further, starlight received simultaneously from the LBT's two separate telescope dishes may be used to monitor and remove internal systematic RV errors. iLocater will: identify "Earth-like" planets orbiting in the habitable-zone around nearby M-dwarf stars; perform the first systematic study of planet occurrence around binary stars as a function of their orbital separation; obtain the first spin-orbit orientation measurements of transiting terrestrial planets; and acquire essential follow-up observations for NASA's planned Transiting Exoplanet Survey Satellite (TESS) mission. In this poster, we present iLocater's design and science cases.

348.21 – PULSE: the Palomar Ultraviolet Laser for the Study of Exoplanets

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PULSE is a project to augment the currently operating 5.1-m Hale PALM-3000 exoplanet adaptive optics system with an ultraviolet Rayleigh laser and associated wavefront sensor. By using a bright (U ~ 7) ultraviolet laser to measure the high spatial and temporal order turbulence near the telescope aperture, where it dominates, one can extend the faintness limit of natural guide stars needed by PALM-3000. Initial simulations indicate that very-high infrared contrast ratios and good visible-light adaptive optics performance will be achieved by such an upgraded system on stars as faint as mV = 16-17 using an optimized low-order NGS sensor. This will enable direct imaging searches for, and subsequent characterization of, companions around cool, low-mass stars for the first time, as well as routine visible-light imaging twice as sharp as HST for

fainter targets. PULSE will reuse the laser and wavefront sensor technology developed for the automated Robo-AO laser system currently operating at the Palomar 60-inch telescope, as well as take advantage of pending optimization of low-order NGS wavefront sensing and planned new interfaces to the PALM-3000 real-time reconstruction computer. PULSE will dramatically extend the AO sky coverage of the telescope from 1% to 50%. More specifically, this will boost the yield from a number of operational exoplanet instruments at Palomar including PHARO, a NIR imager, spectrograph, and coronagraph; a fiber nulling interferometer; and Project 1640, a coronagraph and IFS. Two additional funded instruments expected to benefit from PULSE in the coming years are the SDC; a NIR/visible self-calibrating vector vortex coronagraph, and DARKNESS; an energy-resolving, photon counting MKIDS camera.

348.22 – The Planetary System to KIC 11442793: A Compact Analogue to the Solar System

Carl Fridlund[1,2], Juan Cabrera[1], Szilard Csizmadia[1], H. Lehman[3], Rudolf Dvorak[4], Davide Gandolfi[5], Heike Rauer[1,6], Anders Erikson[1], Claudia Dreyer[1], Philipp Eigmueller[1], Artie Hatzes[3]
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Since exoplanets were first recognized, interpretations have concentrated on dynamics, since the most precise data come from radial velocity (RV) measurements. It is, recently, transit observations, obtained from space (CoRoT and Kepler) that have begun to acquire planetary radii with good precision. Mated to the RV data one can determine the average density of exoplanets and do planetology. We announce the discovery of a planetary system with 7 transiting planets around a Kepler target, a current record for transiting systems. Planets b, c, e and f are reported for the first time by our team (ApJ, accepted) Planets d, g and h were previously reported in the literature, although here we revise their orbital parameters and validate their planetary nature. Planets h and g are gas giants and show strong dynamical interactions. The orbit of planet g is perturbed in such way that its orbital period changes by 25.7h between two consecutive transits during the length of the observations, which is the largest such perturbation found so far. The rest of the planets also show mutual interactions: planets d, e and f are super-Earths close to a mean motion resonance chain (2:3:4), and planets b and c, with sizes below 2 Earth radii, are within 0.5% of the 4:5 mean motion resonance. This complex system presents some similarities to our Solar System, with small planets in inner orbits and gas giants in outer orbits. It is, however, more compact. The outer planet has an orbital distance around 1 AU, and the relative position of the gas giants is opposite to that of Jupiter and Saturn, which is closer to the expected result of planet formation theories. The dynamical interactions between planets are also much richer.

348.23 – WISE Zoo: Discovering Disks In The WISE Database

Michelle Thaller[1]
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Contributing teams: Marc Kuchner, Deborah Padgett, Mike McElwain, and Carol Grady (NASA Goddard), John Debes (STScI), Scott Kenyon (Smithsonian/CfA), Thayne Currie (U. Toronto), Laura Whyte, Ed Padget, Chris Lintott, Alissa Bans and Arfon Smith (Adler Planetarium), Luisa Rebull (IPAC), Kevin Schawinski (ETH Zurich)

The new WISE Zoo project will scour the data archive from NASA's WISE mission to fill in our knowledge of the distribution of protoplanetary and debris disks among stars of various populations. Using the power of citizen science to perform a robust, well-calibrated search, we stand to increase the pool of known debris disks by ~375, mostly by finding new disk candidates around B6-A6 dwarfs, A-F subgiants, and G-K giants. This new sample will trace the evolution of planetary systems around intermediate-mass stars from their youth through retirement and provide a crucial list of future targets for disk and exoplanet imaging with JWST.

348.24 – Optimized spectral sampling for next generation spectrographs

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Over the past twenty years, technological improvements have led to a steadily decreasing lower mass limit for detectable exoplanets. Throughout these past two decades detectable radial velocity semi-amplitudes have always been larger than the intrinsic stellar noise of the quietest of stars. However, this is no longer the case. To continue to lower the mass detection limit of the radial velocity method, we can no longer ignore the intrinsic stellar noise, or simply add this astrophysical jitter in quadrature to our errors. Instead we must explore methods of disentangling it from the signals induced by orbiting planets. One method that has long been used to gauge stellar activity is line bisector analysis, but to our knowledge the optimal spectral sampling for line bisectors has never been explored. We have created synthetic spectral lines, modeled the affects of magnetic activity, and calculated how variations in magnetic activity affect line bisectors. We then used these results to

calculate the optimal spectral sampling size for line bisector analysis. In order to detect Earth-like planets, the next generation of radial velocity machines must be built with the measurement of stellar signals in mind, not the detection of planets. These results are therefore helpful for the design of future high resolution spectrographs that have the goal of measuring and disentangling astrophysical affects from the signals induced by orbiting Earth-like planets.

348.25 – Measuring Transit Signal Recovery in the Kepler Pipeline II: The First Multi-Quarter Results

Jessie Christiansen[1]

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Contributing teams: the Kepler Completeness Working Group

We present the latest results in our continuing investigation of the detection sensitivity of the Kepler science pipeline across multiple quarters. We inject many thousands of targets across the Kepler field of view with simulated transit signals at the pixel level. By processing these pixels through the pipeline as normal, we can then quantify the recoverability of a given transit signal in an average Kepler light curve. These kinds of investigations are essential for determining an accurate value for eta_Earth.

349 – Astrobiology Poster Session

Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

349.01 – A Mid-Infrared Search for Kardashev Civilizations

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We are using the WISE all-sky Source Catalog to search for and put upper limits on the existence of extraterrestrial civilizations with large energy supplies. Any galaxy-spanning (Type III) civilization with an energy supply of more than about one percent of its stellar luminosity will have detectable mid-infrared excess, and nearby (extended) galaxies with civilizations with supplies more than about 80% of their stellar luminosity will be well-distinguished from nearly all natural sources in WISE color-color space. Mid-infrared spectra, far-infrared photometry, and radio emission from CO can all be used to distinguish extraterrestrial mid-infrared radiation from dust.

349.02 – Micelles Protect and Concentrate Activated Acetic Acid

Zoe Todd[1], Christopher House[1]
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As more and more exoplanets are discovered and the habitability of such planets is considered, one can turn to searching for the origin of life on Earth in order to better understand what makes a habitable planet. Activated acetic acid, or methyl thioacetate, has been proposed to be central to the origin of life on Earth, and also as an important energy currency molecule in early cellular evolution. We have investigated the hydrolysis of methyl thioacetate under various conditions. Its uncatalyzed rate of hydrolysis is about three orders of magnitude faster (K = 0.00663 s^-1; 100°C, pH 7.5, concentration = 0.33mM) than published rates for its catalyzed production making it unlikely to accumulate under prebiotic conditions. However, we also observed that methyl thioacetate was protected from hydrolysis when inside its own hydrophobic droplets. We found that methyl thioacetate protection from hydrolysis was also possible in droplets of hexane and in the membranes of nonanoic acid micelles. Thus, the hydrophobic regions of prebiotic micelles and early cell membranes could have offered a refuge for this energetic molecule increasing its lifetime in close proximity to the reactions for which it would be needed. Methyl thioacetate could thus be important for the origin of life on Earth and perhaps for better understanding the potential habitability of other planets.

349.03 – Seeding Life on the Moons of the Outer Planets via Lithopanspermia

Rachel Worth[1,2], Steinn Sigurdsson[1,2], Christopher House[1,2]
1. Penn State University, University Park, PA, United States. 2. Penn State Astrobiology Research Center, University Park, PA, United States.

Material from the surface of a planet can be ejected into space by a large impact, and could carry primitive life forms with it. We performed n-body simulations of such ejecta to determine where in the Solar System rock from Earth and Mars may end up. We find that, in addition to frequent transfer of material among the terrestrial planets, transfer of material from Earth and Mars to the moons of Jupiter and Saturn is also possible, but rare. We expect that such transfer is most likely during the Late Heavy Bombardment or during the next one or two billion years. At this time, the icy moons were warmer and likely had little or no icy shell to prevent meteorites from reaching their liquid interiors. We also note significant rates of re-impact in the first million years after ejection. This could re-seed life on a planet after partial or complete sterilization by a large impact, which would aid the survival of early life during the Late Heavy Bombardment.

349.04 – Beyond the Drake Equation: On the Probability of the Nature of Extraterrestrial Life Forms in Our Galaxy Today

Harold A. Geller[1]
1. George Mason University, Burke, VA, United States.

I will discuss my research into the issues associated with the nature of any extraterrestrials that may be encountered in the future in our galaxy. This research was sparked by statements made by Stephen Hawking in 2010 regarding his fear of emitting radiation from our Earth so that an extraterrestrial intelligent civilization may be alerted to our existence in the galaxy today. While addressing issues of extraterrestrial altruism, a probabilistic equation was developed which addresses the number of extraterrestrial intelligent life forms that may exist in our galaxy today, who could use our bodies for nourishment or reproductive purposes. The equation begins with the results from a Drake Equation calculation, and proceeds by addressing such biochemical parameters as the fraction of ETIs with: dextro sugar stereo-isomers; levo amino acid stereo-isomers; similar codon interpretation; chromosomal length and, similar cell membrane structure to allow egg penetration.

349.05 – Galactic Cosmic Ray (GCR) Model of Titan and Formation of HCNO Exobiological Molecules

Edward C. Sittler[1], John F. Cooper[1]
1. NASA'S GSFC, Greenbelt, MD, United States.

Saturn as a system has two very exotic moons Titan and Enceladus. Space radiation effects at both moons, and as coupled by the Saturn magnetosphere, could lead to the evolution of exobiological models at Titan composed of HCNO molecules. At Titan Cassini discovered that 1) keV oxygen ions, evidently from Enceladus, are bombarding Titan's upper atmosphere (Hartle et al., 2006a,b) and 2) heavy positive and negative ions exist in significant abundances within Titan's upper atmosphere (Coates et al., 2007). Polycyclic Aromatic Hydrocarbons (PAHs) and fullerenes could form in Titan's ionosphere. Laboratory measurements indicate that fullerenes, which are hollow carbon shells, can trap the keV oxygen ions. Clustering of the fullerenes with PAHs and the dominant nitrogen molecules could form larger aerosols enriched in trapped oxygen. Aerosol precipitation could then convey these chemically complex structures deeper into the atmosphere and to the moon surface. We estimate that GCR irradiation should dominate the chemical processing of the aerosols on the surface into more complex organic forms such as tholins and amino acids. To further quantify our results, we have developed an advanced model of GCR interaction with Titan's atmosphere, surface and sub-surface. The model shows dose rates $\sim 8 \times 10\text{-}6$ ergs/cm2/s at the surface which is $\sim 4.2 \times 10\text{-}9$ erg/gm/s for tholin mass density ~ 1.8 gm/cm3. The GCR are found to penetrate $\sim 50\text{-}100$ m below the surface and may therefore also reach the bottom of Titan's methane-ethane lakes. Reggie Hudson et al. (2008) showed that G-factor ~ 0.001 for Glycine. They used pure Acetonitrile CH3CN ices with very small water levels $\sim 0.01\%$ for O. So using $G \sim 0.001$ and GCR surface energy flux noted above at Titan's surface we estimate abundance levels $\sim 2\text{-}10$ ppb of amino acids such as Glycine over 450 Myr period. Therefore, we conclude that this synergy of Saturn system, exogenic irradiation, and molecular processes provide a potential pathway for accumulation of prebiotic chemicals on the surface of Titan.

350 – Circumstellar Disks Poster Session
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

350.01 – Colliding dust grains in a turbulent protoplanetary disk

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Collision rates and velocities of meso-scale dust grains in a protoplanetary disk are important determining factors in the formation of planetary systems. Collisional velocities dictate the outcome of collisions, whether it be grain growth or fragmentation, while the collision rates can be used to give a timescale for growth. This work models the conditions of a protoplanetary disk in the earliest stages of planetesimal formation using numerical simulations of synthetic turbulence. The simulations study the eects due to a combination of turbulence and gravity on the relative velocities and separations of particle pairs. We found marked dierences between simulations with turbulence alone and simulations combining turbulence and gravity. The presence of gravity created different spatial distributions and shifted velocity distributions of particle pairs into lower velocity ranges, possibly alleviating the problems associated with fragmentation.

350.02 – Modeling of Expected PICTURE Observations of Exozodiacal Dust Around Epsilon Eridani

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The PICTURE (Planetary Imaging Concept Testbed Using a Rocket Experiment) sounding rocket will use a visible nulling coronagraph to characterize the exozodiacal dust disk of Epsilon Eridani (K2V, 3.22 pc) in reflected visible light to an inner radius of 1.5 AU (0.5") from the surface of the star. The first launch of PICTURE suffered a telemetry failure and the primary mirror was shattered upon landing. A new launch is scheduled and the PICTURE payload is currently undergoing refurbishment, including receiving a new SiC primary mirror. PICTURE visible light observations will constrain scattering properties of the Epsilon Eridani exozodiacal dust disk and measure the background brightness of the system which must be overcome for future exoplanet observations. Additionally, PICTURE will demonstrate operation of a MEMS deformable mirror and a visible nulling coronagraph in space. Improved modeling and post-flight measurement of instrument performance allow us to present refined exozodiacal dust sensitivities.

350.03 – Searching for faint exozodi: pushing the precision limits of ground-based mid-IR photometry

Joseph Trollo[1], Stanimir Metchev[1]
1. The University of Western Ontario, London, ON, Canada.

We present results from a pilot study to test the viability of precision mid-infrared differential photometry from the ground. We obtained mid-infrared photometry of exozodi candidates in alternating narrow-band filters across the ten-micron silicate feature with T-ReCS on Gemini South. While we did not confirm any of the candidate exozodi, our results demonstrate that we can achieve low photometric uncertainties for faint objects even under sub-median atmospheric conditions. Our analysis shows that we are limited not by the thermal background emission but by the detector readout noise. We are able to push photometric limits and maintain readout-noise dominated uncertainties for faint objects down to magnitudes of 6 mag (0.1 Jy) at 10 micron. As our uncertainties have not yet reached the thermal background-limited regime, there is room for improvement in future mid-infrared instruments, and a potential to observe even fainter objects from the ground with similar or better precision.

350.04 – Exozodi disk models for the HOSTS survey on the LBTI

Mark Wyatt[1], Grant Kennedy[1], Andrew Skemer[2], Geoffrey Bryden[3], William C. Danchi[4], Denis Defrere[2], Chris Haniff[1], Philip Hinz[2], Bertrand Mennesson[3], Rafael Millan-Gabet[5], Olja Panic[1], George Rieke[2], Aki Roberge[4], Gene Serabyn[3], Andrew B. Shannon[1], Karl R. Stapelfeldt[4], Alycia J. Weinberger[6]
1. University of Cambridge, Cambridge, United Kingdom. 2. University of Arizona, Tucson, AZ, United States. 3. NASA JPL, Pasadena, CA, United States. 4. NASA GSFC, Greenbelt, MD, United States. 5. NExScI, Pasadena, CA, United States. 6. Carnegie Inst of Washington, Washington, DC,

United States.
Contributing teams: LBTI-HOSTS

This poster describes a simple model for exozodiacal emission that was developed to interpret observations of the Hunt for Observable Signatures of Terrestrial planetary Systems (HOSTS) project on the Large Binocular Telescope Interferometer (LBTI). HOSTS is a NASA-funded key science project using mid-infrared nulling interferometry at the LBTI to seach for faint exozodiacal dust (exozodi) in the habitable zones of nearby stars. The aim was to make a model that includes the fewest possible assumptions, so that it is easy to characterize how choices of model parameters affect what can be inferred from the observations. However the model is also sufficiently complex that it can be compared in a physically meaningful way with the level of dust in the Solar System, and can also be readily used to assess the impact of a detection (or of a non-detection) on the ability of a mission to detect Earth-like planets. Here we describe the model, and apply it to the sample of stars being searched by HOSTS to determine the zodi level (i.e., the number of Solar System zodiacal clouds) that would be needed for a detection for each star in the survey. Particular emphasis is given to our definition of a zodi, and what that means for stars of different luminosity, and a comparison is given between different zodi definitions justifying our final choice. The achievable exozodi levels range from 1-20 zodi for different stars in the prime sample for a 0.01% null depth, with a median level of 2.5 zodi.

350.05 – Target Selection for the LBTI Hunt for Observable Signatures of Terrestrial Planetary Systems

Alycia J. Weinberger[1], Aki Roberge[2], Grant Kennedy[3], Philip Hinz[4], Geoffrey Bryden[5], Denis Defrere[4], Mark Wyatt[3], Karl R. Stapelfeldt[2], George Rieke[4], William C. Danchi[2], Bertrand Mennesson[5], Rafael Millan-Gabet[6], Gene Serabyn[5], Andrew Skemer[4]
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Contributing teams: LBTI-HOSTS

The Hunt for Observable Signatures of Terrestrial planetary Systems (HOSTS) on the Large Binocular Telescope Interferometer (LBTI) will survey nearby stars for faint exozodiacal dust (exozodi). About 20% of field stars have cold debris disks created by the collisions and evaporation of planetesimals. Much less is known about warm circumstellar dust, such as that found in the vicinity of the Earth in our own system. This dust is generated in asteroidal collisions and cometary breakups, and current detection limits are at best ~500 times our system's level, i.e. 500 zodi. LBTI-HOSTS will be the first survey capable of measuring exozodi at the 10 zodi level (3?). Exozodi of this brightness would be the major source of astrophysical noise for a future space telescope aimed at direct imaging and spectroscopy of habitable zone terrestrial planets. Detections of warm dust will also reveal new information about planetary system architectures and evolution. We describe the target star selection by the LBTI Science Team to satisfy the goals of the HOSTS survey -- to fully inform target selection for a future exoEarth mission. We are interested in actual stars likely to be observed by a mission and stars whose observation will enable sensible extrapolations to those stars that cannot be observed. We integrated two approaches to generate the HOSTS target list. The mission-driven approach concentrates on F, G, and K-type stars that are the best targets for future direct observations of exoEarths, thereby providing model-independent "ground truth" dust observations. However, not every potential target of a future exoEarth mission can be observed with LBTI. The sensitivity-driven approach selects targets based only on what exozodi sensitivity could be achieved, without consideration of exoEarth mission constraints. This naturally selects more luminous stars (A and early F-type stars). In both cases, all stars are close enough to Earth such that their habitable zones are resolvable by LBTI and bright enough at N-band (10 µm) to provide excellent sensitivity. We also discuss observational and astrophysical motivations for excluding binaries of certain separations.

350.06 – An interferometric mini-survey of dust disks around post-AGB stars

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Contributing teams: CHARA Team

We present direct near-IR measurements of sizes and asymmetry of compact dust in a small sample of post-AGB and RV Tauri stars, using the CHARA interferometer array. There is a body of evidence, including, but not limited to, spectral signatures, peculiar chemistry of the photospheres, and some interferometric measurements, that point to stable, Keplerian circumbinary dust disks in these systems. These objects are precursors of Planetary Nebulae, and establishing asymmetries in the dust is of special importance. This work is the first to provide direct evidence of compact asymmetric dust and establish sizes for a representative sample of this class of objects. We report the results of fitting geometric disk and ring models for six objects for which long (200-300m) baseline measurements firmly establish the stellar flux contribution, usually a source of large uncertainty in establishing size scales of circumstellar dust. For three other stars, we rely on spectroscopic measurements to establish the stellar flux. The measured sizes are consistent with the primarily SED-based "wall" model, similar to the Herbig Ae/Be disk models in many aspects. Optical/IR interferometry plays a crucial role in our current understanding of the Herbig disks. We expect this work to be the first step on a similar path to advancing the post-AGB disk

models.

350.07 – A Spitzer and Herschel Study of the Protoplanetary Disk Around the Young Nearby System V4046 Sgr

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1. Rochester Institute of Technology, Rochester, NY, United States. 2. Osservatorio Astrofisico di Arcetri, Florence, Italy.

We present results from a spectroscopic Spitzer and Herschel mid-to-far-infrared study of the circumbinary disk orbiting V4046 Sgr. V4046 Sgr is a ~12 Myr-old spectroscopic binary that is still surrounded by, and is actively accreting from, a gaseous protoplanetary disk. The disk's apparent longevity may be evidence for ongoing planet formation, or could be due to the influence of a distant tertiary (stellar) component. We report detections of emission lines of Ne II, Ar II, H_2 and HCN in the Spitzer spectrum, as well as tentative detections of H_2O and OH. The Herschel spectrum reveals emission from O I, OH, and, tentatively, high-J transitions of CO. Modeling of the silicate dust grains reveals that the inner disk is composed mainly of large amorphous pyroxine and olivine grains (~85% by mass) and a small amount of crystalline silicates (~15% by mass). These results are consistent with other lines of evidence indicating that planet building is ongoing in regions of the disk within ~30 AU of the central, close binary. We compare these results for V4046 Sgr to those for TW Hya, whose disk is similarly evolved but apparently orbits a single star. Combined with our previous and ongoing X-ray and radio studies of the V4046 Sgr system, the Spitzer and Herschel results will shed much-needed light on protoplanetary disk dissipation and planet formation processes in close binary systems. This research work is based in part on observations made with Herschel, a European Space Agency Cornerstone Mission with significant participation by NASA; support was provided by NASA through an award issued by JPL/Caltech. Additional support is provided by by National Science Foundation grant AST-1108950 to RIT.

350.08 – The Effects of Internal Stellar Modes on the Evolution of Protoplanetary Star-Disk Systems

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The theory of the mechanisms driving the evolution of protoplanetary star-disk systems is constantly advancing. Angular momentum transport through the system is a particularly interesting subject due to the difference in specific angular momenta between the evolved star and the Molecular Cloud from which it forms. The decrease observed in the spin rates from young stars to old stars suggests that angular momentum within the system inherently moves from the star to the surrounding disk over time. Previous research models of protostellar systems include a differentially rotating, self-gravitating, polytropic disk around a central point mass. Our project refines this research by replacing the point mass with a resolved, uniformly rotating protostar, allowing internal stellar structure to exist. We then consider how modes internal to the star, through gravitational coupling to the disk modes, provide a means for angular momentum transport from the star to the disk and alter the evolution of the system.

350.09 – An Infrared Examination of Young Stars in Upper Centaurus Lupus

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Optical studies of the Upper Centaurus Lupus (UCL) region of the Scorpius-Centaurus (Sco-Cen) complex have found many young stellar objects. The nearby G/K/M Sco-Cen members have been estimated to be much younger (~10 Myr) than similar star associations (Song, et al 2012). We have assembled infrared data for the objects thought to be members of UCL by mining various archives including the 2-Micron All-Sky Survey (2MASS), the Spitzer Heritage Archive (SHA), specifically the Spitzer Enhanced Imaging Products Source List, and the Wide-field Infrared Survey Explorer (WISE) all-sky source catalog. We created spectral energy distributions (SEDs) and color-magnitude diagrams (CMDs) with multiple wavelengths to identify infrared excesses and determine what fraction of these stars have circumstellar disks. Students from three high schools

350.10 – Herschel-resolved Outer Dust Belts of Two-belt Spitzer Debris Disks around Nearby A-type and Solar Type Stars

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We use Herschel dualband PACS photometry for a unique set of stars that host ongoing activity in the terrestrial planet zones and evidence of an outer/colder dust component, to continue the exploration, begun with Spitzer Space Telescope, of their disk structure and composition. The solar and Atype stars in this sample have combined Spitzer IRS+MIPS (5 to 70 μm) and Herschel PACS (100 and 160 μm) SEDs revealing a tworing disk architecture that mirrors that of the asteroidal-Kuiper belt geometry of our own solar system. Herschel provides the observational sensitivity at PACS 100 μm required to successfully detect and resolve the outer dust belts. Spatially resolved systems can help breach the degeneracy between the grain properties and the dust's radial location, important for SED modeling. In summary, the PACS observations: 1) establish the location and characteristic dust temperature of the outer/cold dust belts and help constrain the minimum grain size and mass; 2) advance our understanding of dust particle composition by constraining the long wavelength emission; 3) facilitate comparison of dust distributions across stellar spectral range; and 4) establish the overall architecture of the circumstellar dust, perhaps pointing to favorable regions where exoplanets may reside.

350.11 – Modeling the Short Timescale Inner Disk Changes of HD169142

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Recent observations of circumstellar disks of gas and dust found around young stars present the unique opportunity for the study of planetary formation regions in their infancy. Observations dating from the early 1990s until the early 2000s on the Herbig Ae star HD169142 show changes in the 1-5 micron fluxes of up to 30%. We present two models for the disk around HD169142 – representing the two distinct flux states observed in the spectral energy distributions, that prior to the year 2000, and that post-2000. The short (~10 years) timescale of the changes demands that whatever changes are made to the models occur within the inner few AU of the disk. In accordance with this and popular consensus on the origin of high near-IR flux in these disks, our models fit the change in near infrared flux by changing the puffed up inner rim by a decrease in its height and length. However, this change alone affects the shadowing of the outer disk and thus affects the far infrared flux levels. Observations from both eras lack any such change in far infrared flux. This might be due to either a tilted inner disk (so changes in shadowing of the outer disk are minimized) or because of the long thermal time scale of the outer disk. This work was supported by NASA ADAP grant NNX09AC73G, Hubble Space Telescope grant HST-GO-13032, and the IR&D program at The Aerospace Corporation.

350.12 – Archival Legacy Investigations of Circumstellar Environments (ALICE): A Resolved Scattered-Light Image of the Debris Disk around HD 202917 from HST/NICMOS

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We have spatially resolved the debris disk around the young (~30 Myr) G dwarf HD 202917 through the analysis of archival HST/NICMOS coronagraphic images. The disk was revealed by reprocessing the images (HST/AR program 11279; PI Schneider) through a novel pipeline that improves the subtraction of the coronagraphic PSF (HST/AR program 12652; PI Soummer). The NICMOS scattered light image confirms an earlier, formally unpublished detection of the disk at optical

wavelengths from HST/ACS coronagraph images. Together, the images show a highly inclined disk extending ~200 AU from the star. We describe preliminary disk models obtained from available photometry and resolved images of the system and the 3D radiative transfer code MCFOST (Pinte et al. 2008), which enables the reconstruction of SEDs and images according to specified dust composition and disk morphology.

350.13 – Archival Legacy Investigations of Circumstellar Environments (ALICE): Debris Disks Newly Resolved in Scattered Light from the HST NICMOS Archive

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We have spatially resolved four new debris disks in scattered light for the first time through the analysis of archival HST NICMOS coronagraphic images. These disks around 12-30-Myr-old main-sequence F or G stars were revealed by reprocessing recalibrated archival images (HST AR program LAPLACE; PI Schneider) with a novel pipeline that improves the subtraction of the PSF (ALICE; Soummer et al. 2012). Three of these disks (HD 30447, HD 35841, and HD 141943) appear to be edge-on, and the fourth (HD 191089) appears to be an asymmetric inclined ring. We describe our modeling efforts so far that take into account all available photometry and resolved images for these sources. We employ the 3D radiative transfer code MCFOST (Pinte et al. 2008), which enables the reconstruction of SEDs and images according to the specified dust composition and disk morphology.

350.14 – Near-IR Scattered Light Imagery of the DoAr 28 Transitional Disk

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Contributing teams: SEEDS/HiCIAO/AO-188 Team

We report the detection of the DoAr 28 transitional disk in H-band polarized scattered light using the HiCIAO coronagraph as part of the Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) survey. The system has an inferred gap based on an observed deficit in its infrared spectral energy distribution; however, we do not detect this gap in our scattered light imagery down to our effective inner working angle of ~23 AU. We discuss the morphology and overall surface brightness of our data, and compare our results to 3D Monte Carlo Radiative Transfer simulations.

350.15 – Ground-based Observations of Water Vapor in Planet-forming Regions

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Spitzer-IRS spectroscopy has shown that protoplanetary disks around low-mass young stars are generally blanketed in the mid-IR with strong molecular emission lines. Observations of these emission lines are allowing us, for the first time, to investigate disk chemistry in planet-forming regions, and to test our understanding of planet formation processes, such as the condensation sequence. However, at the spectral resolution of the IRS, the emission lines are unresolved and blended, making their interpretation difficult, even in the context of sophisticated radiative transfer disk modeling. In addition, with Spitzer alone, we are primarily sensitive to the few-AU region of protoplanetary disks, but do not get a complete picture of the water chemistry throughout the disk. Therefore, we have been pursuing a campaign of ground-based observing of water vapor in protoplanetary disks, utilizing a range of high-resolution spectrographs probing near- through mid-infrared wavelengths. I will present an update on our ground-based observing program and discuss implications for disk chemistry and planet formation.

350.16 – HST Imaging of New Edge-on Circumstellar Disks in Nearby Star-forming Regions

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Edge-on, optically thick circumstellar disks have been previously imaged at subarcsecond resolution around about a dozen nearby young stellar objects. In these systems the central star is occulted from direct view, bright star image artifacts are absent, and the disk reflected light is clearly seen. Comparison of Hubble Space Telescope (HST) edge-on disk images with scattered light models has allowed key disk structural parameters and dust grain properties to be determined. Edge-on disks have been systematically undercounted to date: while 10% of young stars should statistically be occulted by their disk, the observed frequency is much less. Thus there is a significant potential for discovering and imaging new examples. Spitzer Space Telescope legacy science programs have provided the first good spectral energy distribution (SED) measurements for the previously known edge-on disks. We have used these as templates to identify new candidates in far-infrared survey datasets. We report on the results of our HST Cycle 19 program to image twenty-one edge-on disk candidates mostly selected from their SEDs. Eleven are well-resolved with radii ranging from 30-300 AU, nine for the first time and six showing highly collimated jets. Outstanding individual sources include one showing remarkably little dust lane chromaticity (consistent with evolved grains), a highly flattened disk with a small scale height (suggestive of dust settling), and an asymmetric disk with a misaligned jet which likely traces tidal perturbations in a binary system. Follow-up work to obtain ancillary data and perform scattered light modeling of the most symmetric disks is now being pursued. The results of this program will guide a new round of searches for these rare but important snapshots of protoplanetary disk evolution.

350.17 – HST Scattered Light Imaging and Modeling of the Edge-On Protoplanetary Disk ESO Halpha 569

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We present new HST ACS observations (F606W and F814W) and detailed models of a recently discovered edge-on protoplanetary disk around ESO Halpha 569, resolved in scattered light. Data was obtained as part of a Hubble campaign (HST program # 12514) designed to double the known sample of resolved edge-on disks around young stars in nearby star forming regions. We model the scattered light images and spectral energy distribution with the radiative transfer code, MCFOST, to probe the distribution of the dust grains and overall shape of the disk (inclination, scale height, dust mass, maximum particle size, inner radius, flaring exponent and surface/volume density exponent). The spectral energy distribution can place constraints on the mass and distribution of grain sizes within a disk, while the scattered light images place constraints on the geometry of the disk. We confirm that ESO Halpha 569 is an optically thick nearly edge-on protoplanetary disk. The observations are best fit by a flared disk with a tapered outer edge, and (for an ISM gas/dust ratio) a disk mass around 10% of the stellar mass.

350.18 – Modeling Planet-Building Stellar Disks with Radiative Transfer Code

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Understanding the nature of the many planetary systems found outside of our own solar system cannot be completed without knowledge of the beginnings these systems. By detecting planets in very young systems and modeling the disks of material around stars from which they form, we can gain a better understanding of planetary origin and evolution. The efforts presented here have been in modeling two pre-transitional disk systems using a radiative transfer code. With the first of these systems, V1247 Ori, a model that fits the spectral energy distribution (SED) well and whose parameters are consistent with existing interferometry data (Kraus et al 2013) has been achieved. The second of these two systems, SAO 206462, has presented a different set of challenges but encouraging SED agreement between the model and known data gives hope that the model can produce images that can be used in future interferometry work. This work was supported by NASA ADAP

350.19 – Modeling the Light Curve of a Rotating, Non-radially Pulsating Star

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Be stars are B-type stars that have emission lines of hydrogen, helium, and other elements due to a circumstellar disk. Be stars rotate near the critical limit, the point where the gravitational force at the equator equals the centrifugal force. Non-radial pulsations combined with the rapid rotation are thought to eject material to form the characteristic disk from which the emission lines originate. We use the Roche model for rapidly rotating stars with a first-order perturbation due to non-radial pulsations to model the flux variations from the stellar photosphere. These model light curves will be compared to photometric observations of Be stars in the open clusters NGC 3766 and NGC 6231 in order to model the pulsations and mass loss from the stellar surface. We would like to thank the National Science Foundation for the grant AST-1109247 and REU site grant PHY-0849416.

350.20 – Imaging and modeling SSTTau J042021+281349, a new prototypical edge-on protoplanetary disk

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We present new high-resolution observations and panchromatic modeling of SSTTau J042021+281349, a 400AU-radius edge-on protoplanetary disk located in the Taurus star-forming region. This object is part of a larger Hubble Space Telescope Cycle 19 program to image new Spitzer-selected candidate edge-on disks. The unique orientation of edge-on protoplanetary disks enables detailed analyses of their vertical structure as well as of their dust properties. We have gathered high-resolution visible and near-infrared scattered light images of the system with the Hubble Space Telescope and adaptive optics system on the Keck II telescope, as well as high-resolution millimeter thermal emission maps with CARMA. Compared to the well-known HH 30 edge-on protoplanetary disk, the SSTTau J042021+281349 system is particularly remarkable because of its spectacular bipolar jet and the extremely high degree of lateral symmetry of the disk. Indeed, this system is a "cleaner" prototype for this category of disks. We also discuss the origin of diffuse scattered light well above the disk midplane, which could be related to a large-scale disk wind entraining small dust grains. Arguably the most remarkable feature of this disk is the apparent achromaticity of dust opacity from the visible to the near-infrared, which suggests that it is in an advanced stage of dust evolution. Our modeling aims at reproducing simultaneously all of these datasets, as well as the Spitzer- and Herschel-populated spectral energy distribution of the system, constraining the disk geometry and constituent dust properties in a self-consistent approach. We build on similar analyses conducted on other edge-on disks to place this object in the overall scheme of protoplanetary disk evolution.

350.21 – Revealing Circumstellar Disks Through NPOI Observations and non-LTE Models

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We present a study comparing non-LTE numerical disk models to interferometric observations of circumstellar disks around B-type stars. Custom software designed to handle both radially symmetric and asymmetric disk models with two distinct halves has been developed that works with BEDISK and BERAY codes developed by Sigut et al. The new analysis software compares model predicted synthetic images at a wide range of inclination angles to interferometric observables and accounts for arbitrary orientations of the major axis of the disk with respect to the north direction on the sky. We demonstrate the robustness of our methodology by applying our new software to observations of two distinct emission-line stars, a B7 subgiant (omicron Aqr) and a B8 supergiant (48 Lib), one selected based on a clear symmetric double-peak profile and the other one selected based on its clear asymmetric double-peak profile. The synthetic images, as well as the density and temperature profiles for the two cases are compared and discussed.

350.22 – Omicron Aquarii: Numerical Analysis of the Circumstellar Disk

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We present the results of a study of the circumstellar disk surrounding the star Omicron Aquarii, where numerical disk models are compared to the spectroscopic and the interferometric data collected using the Solar Stellar Spectrograph at the Lowell Observatory's John S. Hall telescope and the Navy Precision Optical Interferometer, respectively. The numerical analysis is based on a quantitative comparison between the Fourier Transform of the synthetic images computed with BEDISK code of Sigut and Jones (2007, ApJ, 668, 481) and the squared visibility data obtained at the NPOI. We also demonstrate how the model dependent synthetic spectrum can be directly constrained by the observed spectrum of the H-alpha emission line. The complementary spectroscopic and interferometric constraints allow for more accurate determination of the density and temperature structure of the disk, including an inclination angle of the disk with respect to the line-of-sight.

350.23 – The Incidence of Debris Disks Around M Dwarfs Within 25pc

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Debris disks are pieces of planetesimals that have been ground into dust by repeated collisions. These disks have thermal equilibrium temperatures in the tens to hundreds of Kelvins, making them prime targets to detect with WISE long wavelength photometry. We utilized 3.6, 4.5, 12, and 22µm WISE data for two volume-limited samples of K and M stars to determine the incidence of debris disks around M dwarfs. The first sample was age-limited to stars younger than ~300Myrs (171 M stars and 1 K star) and the second was volume-limited only (755 M stars and 310 K stars). We found a total of 4 debris disks in our age-limited sample (4 M and 0 K stars) and a total of 11 debris disks in our volume-limited only sample (10 M and 1 K stars). This gives us a total warm-disk detection rate of 1.5% for M stars and 0.3% for K stars. We determined that the disks we detected have inner radii between 0.15 and 1.4 AU and fractional luminosities between 8.12x10-5 and 1.31x10-2. This work is supported by the NSF REU program at Northern Arizona University.

350.24 – Resolved Millimeter-Wavelength Observations of Debris Disks around Sun-like Stars

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The presence of debris disks around young main sequence stars hints at the structure of hidden planetary systems. Spatially resolved observations are crucial to characterize the structure of the dust disk. The FEPS (Formation and Evolution of Planetary Systems) Spitzer Legacy survey of nearby young solar analogues yielded a sample of five stars with millimeter flux excesses suitable for interferometric follow-up. We present observations with the Submillimeter Array (SMA) and the Combined Array for Research in Millimeter-wave Astronomy (CARMA) at ~2 arcsec resolution that spatially resolve the debris disks around five nearby (d~50 pc) young solar analogues. Three of the five disks are spatially resolved for the first time by these observations. We simultaneously model the broad-band photometric data and spatially resolved millimeter visibilities of the systems to constrain both the dust temperatures and disk morphologies. We fit for basic structural parameters, including the inner radius and width of the debris ring, the total mass of the disk, and the characteristic dust grain size. We inspect the properties of the sample in order to gain insight into the range of morphologies of young planetary systems around Sun-like stars, and place the dust observations in context by comparing them with the Booth et al. (2012) sample of resolved debris disks around A stars.

350.25 – Planetary Remnants Orbiting White Dwarfs

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A recent cross-correlation between the SDSS DR7 White Dwarf Catalog with the Wide-Field Infrared Survey Explorer (WISE) all-sky photometry at 3.4, 4.6, 12, and 22 microns performed by Debes et al. 2011 resulted in the discovery of 52 dusty white dwarfs. The 6'' WISE beam allows for the possibility that many of the excesses exhibited by these white dwarfs may be due to contamination from a nearby source, however. We present MMT+SWIRC J- and H-band imaging observations (0.5-1.5'' PSF) of 16 of these candidate dusty white dwarfs and confirm that 4 have spectral energy distributions consistent with a dusty disk and do not have a nearby source contaminant. The remaining 12 have contaminated WISE photometry and SEDs inconsistent with a dusty disk when the contaminating sources are not included in the photometry.

350.26 – Analysis of Hydrogen Recombination Masers Around MWC349A

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We present new 230 GHz and 350 GHz Submillimeter Array observations of the maser emission originating from the circumstellar disk surrounding the B[e] star MWC349A. We carried out centroid fitting on high signal-to-noise ratio H26α and H30α data to derive the spatial distribution of H30α and H26α maser spots over a 60 mas x 40 mas field with milliarcsecond precision. Using this new data we determine that one group of maser spots are located in a linear region likely originating from a thin, edge-on, Keplerian disk. Other maser spots are distributed off of this linear structure consistent with the presence of an ionized outflow from the main disk structure. Based on the spatial distribution of maser spots and the relative slopes of the H26α and H30α position-velocity diagrams, we demonstrate that the H26α maser spots are located 20% closer to the disk center than the H30α maser spots. This agrees with predictions of previously published radiative transfer models of MWC349A. Our high-precision maps and new information on the spatial distribution of H26α maser spots promise to allow us to produce a detailed geometric model of the disk structure.

350.27 – A WISE Survey of Circumstellar Disks in Taurus

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Complete samples of circumstellar disks in star-forming regions and accurate classifications of those disks represent a foundation for studies of star and planet formation. Using data from the Wide-field Infrared Survey Explorer All-Sky Release Catalog and other catalogs of ancillary data, we have 1) analyzed all known members of the Taurus star-forming region for infrared excess, indicative of disk presence, and estimated the evolutionary stages of detected disks and 2) searched for new members of Taurus by identifying sources with red mid-infrared colors. Through the latter, we have confirmed 25 new members with optical and infrared spectra. The census of disk-bearing stars in Taurus should now be largely complete.

350.28 – Transitional Disks Associated With Intermediate-Mass Stars in the SEEDS Survey

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Contributing teams: SEEDS Consortium

The Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) survey has included observations of a number of disks associated with intermediate mass stars. Protoplanetary disks in the survey have polarized intensity images showing the expected depolarization along the disk major axis, if observed when the NIR excess is low, and can be non-detections if the excess is in a high state, resulting in shadowing of the disk. A focus of our survey is Meeus group I Herbig star disks, which have been proposed to be transitional and pre-transitional disks associated with intermediate-mass stars, rather than flared, protoplanetary disks. We find disks with evidence for partially cleared gaps, as well as disks with polarization divots, cleared annuli and/or shadows, partial shadowing of the outer disk, and spiral arms. Some disks have several of these features. We discuss our survey results in terms of spiral arm theory, dust trapping vortices, and the extent to which spiral arm detections are linked to large relative disk scale heights. Grady is supported under NSF AST 1008440 and through the NASA Origins of Solar Systems program on NNG13PB64P.

350.29 – Discovery and Variability of More Than 100 New Be Stars with SDSS-III/APOGEE

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More than 100 new, and many more previously-known Be stars have been identified among the hot telluric standard stars used by the Apache Point Observatory Galactic Evolution Experiment (APOGEE). Multi-epoch observations of these stars have accumulated over 700 high-resolution H-band spectra, revealing among a wealth of other variability, a subset of the stars transitioning between B and Be phases. For these stars, emission in the Brackett series lines either disappears over time or appears unexpectedly for what appeared to be a normal B star. Identifications and high-resolution spectra for more than 100 new Be stars are presented, in addition to analysis of the H-band variability and the timescales over which it is observed.

350.30 – Optical Spectroscopy of Be Stars Identified in SDSS-III/APOGEE Data

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In its first two years of operation the Apache Point Observatory Galactic Evolution Experiment (APOGEE) has acquired data on over 170 Be stars, providing the largest sample of high-resolution H-band spectra for Be stars to date. Roughly 72% of the new Be stars had been observed spectroscopically in the past, but did not show evidence of line emission at the time and hence were classified in the literature as normal OBA stars. The remaining 28% were observed spectroscopically for the first time with APOGEE, meaning that their optical spectral properties have never been investigated. We present the preliminary results of an optical spectroscopy follow-up campaign, in order to determine or update temperature and luminosity classifications and measure the stellar rotational velocities for some of the newly-identified Be stars. These quantities are used to sub-classify the stars and to determine the extent of the Brackett series-emitting region of Be disks.

350.31 – Extending Accretion Diagnostics to the Mid-Infrared Wavelengths

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The accretion of matter from circumstellar disks onto young stars sets the final stellar mass and contributes to the evolution and dispersal of protoplanetary disks. The rate at which a star is accreting from the circumstellar disk can be estimated using a variety of gas lines spanning from the UV to the near-IR (e.g., Alcala' et al. 2013). Thanks to the Spitzer Space Telescope, which has revealed a forest of gas lines in the mid-IR in young stars, it is nowadays possible to extend this analysis of the accretion indicators to longer wavelengths, where extinction is lower. To this aim, we have re-reduced and analyzed a sample of ~60 objects in different evolutionary stages observed with the High-resolution module of the InfraRed Spectrograph. We find that the Hydrogen line transitions in the mid-IR (HI at 12.37 and 11.31µm) are bright and common in the Spitzer spectra. Based on the line intensities, ratios and correlation with known accretion indicators at shorter wavelength, we introduce these lines as accretion indicators. We analyze the possibility of using these lines to estimate the accretion from embedded objects, where the other lines fail due to the high-extinction produced by the envelope. We also investigate the presence of these gas lines in old objects, surrounded by a debris disk. This preliminary work paves the way to follow-up ground based observations that can spectrally resolve the lines and to more sensitive observations toward old objects with JWST.

350.32 – Misaligned Protoplanetary Disks in a Young Binary System: Sufficient Misalignment to Drive Kozai Oscillations of Planetary Orbits

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Many extrasolar planets follow orbits that differ from the nearly coplanar and circular orbits found in our solar system. Planets' orbits may be eccentric or significantly inclined with respect to the host star's equator, and the population of giant planets orbiting very close to their host stars suggests significant orbital migration. There is currently no consensus on what causes the migration and produces inclined or eccentric orbits. Theoretical explanations often invoke interactions with a binary companion star on an orbit that is inclined relative to the planet's orbital plane. Such mechanisms require significant mutual inclinations between planetary and binary star orbital planes, which until now have not been measured. Here we

show that at least one of the protoplanetary disks in the young binary system HK Tau is significantly inclined to the binary orbital plane. Our ALMA observations of the molecular gas in the system show that both stars have protoplanetary disks in Keplerian rotation, the first time that disk rotation has been detected around both stars in a binary. The two disk planes are misaligned by roughly 60° from each other, so at least one of the disks is inclined 30° or more from the binary orbital plane. Our results demonstrate that the necessary conditions exist for misalignment-driven mechanisms to modify planetary orbits. The misalignment is present at the time of planet formation, and it is apparently a part of the binary formation process. Thus, binary companions may be important drivers of the diversity of orbits seen in extrasolar planets. This paper makes use of the following ALMA data: ADS/JAO.ALMA#2011.0.00150.S. ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada) and NSC and ASIAA (Taiwan), in cooperation with the Republic of Chile.

351 – Dust Poster Session
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

351.01 – The UV Interstellar Extinction Properties in M31

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Radiative transfer modeling of external galaxies indicates that the "standard" Milky-Way-type dust extinction relation does not provide the best fit to many extragalactic SEDs. SMC-type dust is often a better fit. Therefore, studies of Local Group galaxies, where the dust properties can be directly measured, are very important to assess the variations in interstellar dust extinction from galaxy to galaxy, and also within a single galaxy. The UV extinction properties of the Milky Way and two sub-Solar metallicity galaxies, the LMC and SMC, have been well studied. However, little is known about other galaxies in the Local Group. Fifteen years ago, we did a "pilot study" using HST/FOS of UV extinction toward a very small sample of OB stars in the high metallicity galaxy, M31. We derived an average M31 extinction curve from only three sightlines that had an overall wavelength dependence similar to that of the average Galactic extinction curve, but potentially possessed a weaker 2175 A bump. While the extinction curves calculated from these data provided a proof-of-concept, the study suffered from low S/N, low extinction, and poorly matched pairs of reddened and unreddened stars. In this new study, we obtained low resolution UV spectra of a sample of reddened and lightly reddened OB stars in M31 with HST/STIS to improve our knowledge of the wavelength dependence of interstellar dust extinction. We will present UV extinction curves that have been constructed for seven reddened sightlines in M31, and compare the wavelength dependence of extinction in M31 with that seen in the Milky Way, LMC, and SMC.

351.02 – Numeric Modeling of Granular Asteroid Growth

Benjamin Beaumont[1], Davide Lazzati[1]
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It is believed that planetesimals and asteroids are created by the constructive collisions of smaller objects, loosely bound under the effect of self-gravity and/or contact forces. However, the internal dynamics of these collisions and whether they trigger growth or fragmentation are poorly understood. Prior research in the topic has established regimes for the results of constructive collisions of particles under contact forces, but neglects gravity, a critical component once particles are no longer touching, and force chains, an uneven distribution of force inherent to granular materials. We run simulations binary collisions of clusters of particles modeled as hard spheres. Our simulations take into account self-gravity, dissipation of energy, friction, and use a potential function for overlapping particles to study force chains. We present here the collision outcome for clusters with variable masses, particle counts, velocities, and impact parameter. We compare our results to other models and simulations, and find that the collisions remain constructive at higher energies than classically predicted.

351.03 – Using Spatially-Resolved Spectroscopy to Study Stardust

Lacey Daniels[1], Angela Speck[1], Nelson De Souza[1], Suklima Guha Niyogi[1]
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We present a study of spatial distribution of different dusty spectral features in the Oxygen-rich Asymptotic Giant Branch star SW-Vir. We have spectral data for 8-14um from Michelle at Gemini North, covering a 10x10 grid centered on the star to yield a set of 100 spectra cover (4 x 4 arcseconds of sky). We analyzed each spectrum by eliminating the continuum and the measuring the parameters (full width at half maximum, peak position, and strength) of the remaining spectral features. To assess the precision of the measurements, we chose to eliminate the continuum in two different ways – dividing and subtracting a fitted power law. We compared the resulting measurements to each other in order to find correlations. We sought correlations between the parameters of the spectral feature as well as between different spectral features and with apparent radial distance from the central star. We did not find any correlation between the equivalent properties when comparing subtracted and divided spectra or between any parameters, even when the parameters of a single continuum-elimination technique were compared. Our results suggest that the standard model for dust formation and/or our attributions of specific compounds to specific spectra features are far too simple.

351.04 – The Fitting of the Broad 8-21 Micron Feature of O-Rich AGB Stars with the Summation of Two Gaussian Curves

David J. Arrant[1], Angela Speck[1]

1. University of Missouri, Columbia, MO, United States.

As the expelled gas from the surface of asymptotic giant branch (AGB) stars drifts away from the star, it cools to condense into dust. The stability of carbon monoxide (CO) will trap most of the oxygen and carbon. The more abundant of oxygen and carbon will have excess atoms available to form dust because the lesser abundant will be entirely trapped in CO. AGB stars are divided into carbon-rich (C-rich) stars or oxygen-rich (O-rich) stars. We have selected a sample of O-rich AGB stars with optically thin dust shells and low mass-loss rates, which have measure metallicities/abundances. These objects show a 8-21 micron feature, which is attributed to various dust species, such as silicates and oxides but no single species gives a satisfactory fit. We fitted this broad feature with two overlapping Gaussian functions in order to determine whether the overlapping spectral features of two significant dust species can explain the observations. The "goodness" of fit of the overlapping Gaussian functions will be discussed and analyzed with different methods.

351.05 – An Exploration of the Dust Spectral Features of the Carbon-Rich Star V Cyg Through Time and Space

Matthew Reel[1], Angela Speck[1], Gregory C. Sloan[2], Kevin Volk[3]
1. University of Missouri, Columbia, MO, United States. 2. Cornell, Ithaca, NY, United States. 3. STScI, Baltimore, MD, United States.

Carbon-rich AGB stars are surrounded by circumstellar shells of gas and dust. The dust is dominated by carbon (probably graphitic) and silicon carbide (SiC), which is the source of the observed 11µm spectral feature. We investigate the nearby carbon star V Cyg which has been observed numerous times over the past few decades. By analyzing the temporal spectral variations associated with the stellar pulsation cycle we study how the pulsation cycle affects the circumstellar dust. The Infrared spectrum of the star also shows many prominent molecular absorption bands, as well as the "30µm" emission feature which has previously been attributed to magnesium sulfide (MgS). In addition to the temporal data, we have also obtained spatially-resolved spectroscopic data for the dust shell(s) around V Cyg. Combining these various spectral observations with AAVSO data on variations in the visual magnitude we investigate temporal variations in both the 11µm and 30µm spectral features and sought to correlate these temporal variations with the spatial variations in the 11µm feature. Our results indicate many spatial correlations within the 11µm feature parameters, as well as correlations which may suggest a carrier of the 30µm feature other than pure MgS.

351.06 – Global Modeling of Dust Evolution in the ISM

Jonathan D. Slavin[1]
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We present preliminary results of our program to model the global evolution of dust in the interstellar medium (ISM). Our approach is to follow individual grains as they move between different phases of the ISM starting from their creation until they are destroyed and subject to various destruction, accretion and agglomeration processes along the way depending on the phase they are residing in at each time. The time spent in each phase is modeled based on the mean lifetime of that phase, but is calculated for each grain "trajectory" based on sampling the probability distribution for the phase lifetime. The transitions between phases can be destructive, as when warm ISM is converted to hot ISM in a fast shock, or not, as when warm ISM evaporates into the hot ISM. Our goal is to understand gas phase depletion patterns, the grain size distribution (and its variability in space) and grain destruction.

351.07 – The effect of aluminum on silicate spectral features

Lucie Williams[1], Angela Speck[1], Alan G. Whittington[1], Anne M. Hofmeister[2], David J. Arrant[1]
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Many astrophysical environments exhibit a spectral feature around 10 microns, which has long been attributed to amorphous silicates. However, the precise composition of almost ubiquitous silicate dust grains remains a mystery. Here we investigate the effect of aluminum on this common spectral feature. Aluminum (Al) is the fourth most abundant metal after Si, Mg, and Fe and is important in the nucleation of dust grains around stars. Furthermore aluminum is found in meteoritic presolar dust grains. Therefore, it is essential to expand our knowledge of how Al affects silicate spectral features. We examine the role of Al in silicate glasses by producing a range of compositions with known physical structure (polymerization or non-bridging oxygens to SiO4 tetrahedra; NBO/T). We have produced a set of 20 glass samples for which we have measured the precise composition and the glass transition temperature. We have calculated the value of NBO/T from the composition and taken mid-infrared spectra of each sample composition. We have measured the spectral parameters: peak position, barycenter, and FWHM of each ~10 micron spectral feature. We then sought trends between the various measured, modeled and calculated parameters. We show that there is a trend between Al content, NBO/T and the peak position of the spectra. Potential applications of these new spectra and their trends are also discussed.

351.08 – Constraining the Spatial Scales and Composition of Dust in the Diffuse Interstellar Medium

Rachel E. Anderson[1], Christine Chen[1], Dean C. Hines[1]
1. STScI, Baltimore, MD, United States.
Contributing teams: IPAC

We have carried out a study to examine the spatial structure and composition of dust in the Diffuse Interstellar Medium, using Spitzer IRAC and MIPS observations of the Lockman Hole and Taurus. Models of the infrared background include three components: scattered light and thermal emission from zodiacal dust, diffuse emission from dust in the Milky Way, and the Cosmic Infrared Background. The Background Model Generator (BMG) developed by IPAC to model the Spitzer background includes all three components (Reach 2000), and it assumes that: 1) the spatial distribution of the diffuse interstellar dust is well-traced out by the emission observed in the COBE DIRBE + IRAS 100 micron all sky map; 2) that the Spectral Energy Distribution of the dust is well-described using the Schlegel, Finkbeiner, & Davis (1998) template. We compare the Spitzer data for these regions to this background model to determine how fine scale structure that is not spatially resolved by COBE and the observed, relative contribution from various emission features from dust, impact our understanding of the diffuse interstellar emission. This in turn enables us to evaluate the efficacy of models based only on the averaged SEDs and low spatial resolution data.

351.09 – Testing the effect of continuum elimination methods on studies of infrared dust features from AGB star spectra

Colby Delisle[1], Angela Speck[1]
1. University of Missouri, Columbia, MO, United States.

Asymptotic Giant Branch (AGB) stars are major contributors of cosmic dust to the interstellar medium. Understanding the cosmic dust ejected from these stars is essential to understanding the broader topics of evolution and composition of stellar and interstellar objects in our universe. AGB stars produce either carbon- or oxygen (O)-rich dust. O-rich AGB stars have been classified into groups according to the shapes of their spectral features in the mid-infrared (IR). Because their spectral features are similar, stars within each group are expected to have similar dust shell parameters, especially with respect to the composition of the dust. We have selected a sample of 26 O-rich AGB stars, in a single group in order to investigate an apparently homogenous group of stars. In particular, we chose stars in group SE1. Using spectral data from the Infrared Space Observatory (ISO), and the Infrared Astronomical Satellite (IRAS) we investigated variations in the spectral parameters of these stars: i.e. continuum temperature, feature strength, peak position(s), FWHM. In this preliminary work we present a study of the effect of the methods by which we eliminate the continuum prior to measuring the feature parameters.

351.10 – Distances and Reddenings for a Billion Stars: Constructing a 3D Reddening Map

Gregory Green[1], Eddie Schlafly[2], Douglas P. Finkbeiner[1]
1. Harvard Univ., Cambridge, MA, United States. 2. MPIA, Heidelberg, Baaden-Wuerttemberg, Germany.

We present a method for constructing a 3D map of Galactic dust reddening, using broadband stellar photometry. We first determine the full probability density of stellar type, distance and dust extinction for observed stars along a line of sight. We then infer the extinction along the line of sight by combining information from the individual stars. For individual stars, our reddening estimates are unbiased, with a scatter of ~0.15 magnitudes in E(B-V), based on comparisons with the SEGUE catalog (Green et al. 2013). Based on comparisons with mock catalogs, we expect to recover stellar distances to within 30% to 50%, depending on stellar type. We have applied this technique to ~650 million stars observed by Pan-STARRS 1 to construct a 3D extinction map out to a distance of several kiloparsecs, probing dust columns of up to ~4 magnitudes in E(B-V). At large distances, our map is in good agreement with the 2D dust map of Schlegel, Finkbeiner and Davis (1998). At intermediate distances, our map reveals large-scale dust structure.

351.11 – A Catalog of Distances to Molecular Clouds from Pan-STARRS1

Eddie Schlafly[1], Gregory Green[2], Douglas P. Finkbeiner[2], Hans-Walter Rix[1]
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We present a catalog of distances to molecular clouds, derived from PanSTARRS-1 photometry. We simultaneously infer the full probability distribution function of reddening and distance of the stars towards these clouds using the technique of Green et al. (2013) (see neighboring poster). We fit the resulting measurements using a simple dust screen model to infer the distance to each cloud. The result is a large, homogeneous catalog of distances to molecular clouds. For clouds with heliocentric distances greater than about 200 pc, typical statistical uncertainties in the distances are 5%, with systematic uncertainty stemming from the quality of our stellar models of about 10%. We have applied this analysis to many of the most

well-studied clouds in the ? > -30° sky, including Orion, California, Taurus, Perseus, and Cepheus. We have also studied the entire catalog of Magnani, Blitz, and Mundy (1985; MBM), though for about half of those clouds we can provide only upper limits on the distances. We compare our distances with distances from the literature, when available, and find good agreement.

352 – Gamma Ray Bursts Poster Session
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

352.01 – Fermi-LAT Observations of GRB 130427A

Sylvia Zhu[1,2], James Chiang[3], Charles D. Dermer[4], Nicola Omodei[5], Giacomo Vianello[5], Shaolin Xiong[6]

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The observations of the exceptionally bright GRB 130427A by the Large Area Telescope (LAT) aboard the Fermi Gamma-ray Space Telescope are providing new constraints on the nature of these unique astrophysical sources. GRB 130427A had the largest fluence, highest-energy photon (95 GeV), longest ?-ray duration (20 hours), and one of the largest isotropic energy releases ever observed from a GRB. The temporal and spectral analyses of the late-time high-energy emission observed by Fermi-LAT of GRB 130427A challenge the widely accepted model that the non-thermal high-energy emission in the afterglow phase of GRBs is synchrotron emission radiated by electrons accelerated at an external shock.

352.02 – Search for Sub-Planckian Length Scales in GRB 090510A and GRB 130427A

Chad Brisbois[1], Robert J. Nemiroff[1], Alexander Kostinski[1]

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The ability of the photons detected from GRB 090510A and GRB 130427A by the LAT instrument aboard NASA's Fermi satellite to constrain the spectrally dispersive properties of cosmological spacetime as predicted by some theories of quantum gravity is assessed. The most constraining photons continue to be, as reported previously, three super-GeV photons detected in GRB 090510A, separated by about 30 GeV in energy, that all arrived within about one millisecond. This suggests that spacetime is not only smooth across the universe at scales below the Planck length, but at scales even 1/500th of the Planck length. Here we report on a search conducted using all Fermi-LAT detected photons from these GRBs -- including those below 1 GeV -- for independent evidence that the universe is smooth at any scale below the Planck length.

352.03 – The Future of Fermi-LAT Gamma-ray Burst Studies with Improved Event Reconstruction

Judith L. Racusin[1]

1. NASA/GSFC, Greenbelt, MD, United States.
Contributing teams: Fermi Large Area Telescope Collaboration

Observations of the extremely energetic Fermi-LAT GRB population over the last 5 years has led to many new insights into GRB emission mechanisms and the presences of gamma-ray afterglows. There is a major effort underway by the instrument team to upgrade the event reconstruction and analysis of Fermi LAT data, which will result in a much-improved dataset of both previously detected bursts, and those yet to be discovered, including better localizations, increased effective area at low energies, and more well-reconstructed gamma-rays. We will present predictions for the science that will be possible with this new dataset, known as Pass 8, including resolving questions regarding the presence of additional components and/or cutoffs in GRB spectra. Initial results have already been presented in Atwood et al. (2013, ApJ, 774, 76).

352.04 – Chasing short duration gamma-ray bursts with Swift and Fermi

Eleonora Troja[1,2], Amy Y. Lien[1,2], Valerie Connaughton[2], Neil Gehrels[2], Veronique Pelassa[2], Eleonora Troja[2]

1. University of Maryland, College Park, MD, United States. 2. NASA/GSFC, GREENBELT, DC, United States.

Short duration gamma-ray bursts (GRBs) are intense flashes of gamma-rays lasting less than two seconds. The common notion that short bursts originate from coalescing compact binaries, either neutron star-neutron star (NS-NS) or neutron star-black hole (NS-BH) mergers, makes them the most promising tool to aid in the direct detection of gravitational waves (GWs) by forthcoming facilities, such as advanced LIGO/Virgo. The Fermi and Swift satellites offer unique, and complementary capabilities for the study of short GRBs. Thanks to its wide field of view, broad energy bandpass, and sophisticated trigger algorithms, the Gamma-Ray Burst Monitor (GBM) on-board Fermi is currently the most prolific detector of short GRBs. The Burst Alert Telescope (BAT) on-board Swift detects only a few short bursts/year, but provides accurate

localizations required for follow-up observations. We present a correlative analysis of the Fermi/GBM and the Swift/BAT data aimed at increasing the sensitivity to short-hard bursts, their rate of detection, and our chance of localization. By comparing the two populations of bursts we characterize the biases introduced by the trigger algorithms, and how they shape the observed population of short bursts. This allows us to calculate a more realistic number for the expected rate of Fermi/GBM events within the ALIGO horizon, and estimate the timescale over which robust constraints to the merger model can be placed by future Fermi/ALIGO searches. We discuss how the current Swift and Fermi strategies could be optimized to increase the number of well-localized short bursts.

352.05 – Distribution of Gamma-Ray Bursts

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Gamma-Ray Bursts (GRBs) are known to be bright, irregular flashes of gamma rays that typically last just a few seconds, believed to be caused by stellar collapse or the merger of a pair of compact objects. Through previous work, it has been found that GRBs are distributed roughly uniformly over the entire sky, rather than being confined to the relatively narrow band of the Milky Way. Using the Python programming language, we generated a model of GRBs over cosmological distances, based on current empirical GRB distributions. The grbsim python module uses the acceptance-rejection Monte Carlo method to simulate the luminosity and redshift of a large population of GRBs, including cosmological effects such as dark energy and dark matter terms that modify the large-scale structure of space-time. The results of running grbsim are demonstrated to match the distribution of GRBs observed by the Burst Alert Telescope on NASA's Swift satellite. The grbsim module will subsequently be used to simulate gamma ray and neutrino events for the Astrophysical Multimessenger Observatory Network.

352.06 – Probing the Gamma-Ray Burst Rate with Trigger Simulations of the Swift Burst Alert Telescope

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The gamma-ray burst (GRB) rate is essential for revealing the connection between GRBs, supernovae and stellar evolution. Additionally, the GRB rate at high redshift provides a strong probe of star formation history in the early universe. While hundreds of GRBs are observed by Swift, it remains difficult to determine the intrinsic GRB rate due to Swift's complex trigger algorithm. Current studies usually approximate the Swift trigger algorithm by a single detection threshold. However, unlike the previously flown GRB instruments, Swift has over 500 trigger criteria based on photon count rate and additional image threshold for localization. To investigate possible systematic biases and explore the intrinsic GRB properties, we developed a program that is capable of simulating all the rate trigger criteria and mimicking the image trigger threshold. We use this program to search for the intrinsic GRB rate. Our simulations show that adopting the Swift's complex trigger algorithm increases the detection rate of dim bursts. As a result, we find that either the GRB rate is much higher at large redshift than previously expected, or the luminosity evolution is non-negligible. We will discuss the best results of the GRB rate in our search, and their impact on the star-formation history.

352.07 – Very High Energy Gamma Ray Bursts: Predictions for New Ground Based Telescopes

Ian Morgan[1, 2], Judith L. Racusin[3], Jeremy Perkins[3]
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Contributing teams: on behalf of the Fermi-Large Area Telescope Collaboration

To date no Gamma Ray Bursts (GRBs) have been detected in the Very High Energy (VHE) Range (100 GeV-100 TeV). However, upgrades to the current generation of ground based air Cherenkov telescopes such as HESS, VERITAS and MAGIC make them more sensitive than ever. Moreover, the next generation water Cherenkov telescope, HAWC, will observe the multi-TeV sky with unprecedented sensitivity and the future Cherenkov Telescope Array will be an order of magnitude more sensitive than the current generation. We take GRBs detected by the Fermi LAT and extrapolate temporally extended emission light curves from the High Energy (HE) (100 MeV-100 GeV) to the VHE energy range. This work systematically characterizes if and how LAT GRBs will be detected by these VHE telescopes. HAWC, with its large field of view and duty

cycle, presents the best candidate, in the near future, for detecting a burst in the VHE range. Furthermore,we predict the detectability of hypothetical bursts based on changes in redshift, zenith angle, and Extragalactic Background Light (EBL).

352.08 – Modeling the Afterglows of Gamma Ray Bursts for Arbitrary Viewing Angles

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We present models of GRB afterglow light curves for simulated GRBs. We describe a method by which the energy distribution of the system can be determined for an arbitrary viewing angle relative to the jet axis. From this distribution, we calculate the time-evolution of the expanding shockwave from the stellar explosion. With relativistic considerations, we can model the synchrotron radiation emitted in this shockwave and construct the time-evolution of the afterglows seen by an observer at an arbitrary angle. We will present results of the calculated afterglow spectra as functions of time for energy distributions from numerical simulations as well as for simple jet models. This work was partially supported by the National Science Foundation's REU program through NSF Award AST-1004881 to the University of Wisconsin-Madison.

352.09 – Modeling the Composition and Emissions of Gamma-Ray Burst Jet Cocoons

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Massive stars end their lives with powerful supernova explosions that, in extreme cases, may produce a gamma-ray burst. The driving mechanisms of these bursts are relativistic jets that propagate through the dense, rapidly rotating star. Previous studies have examined the general formation and photospheric emissions of the cocoons of these jets. However, the structure of the cocoon and the effect of cocoon composition on the creation of the gamma-ray burst have not yet been determined. In this study, we present the results of numerical simulations aimed at determining the composition and mixing of the cocoon material in gamma-ray burst progenitors and study how mixing affects the emitted radiation. We do so by adding tracer particles to special relativistic hydrodynamic simulations of collapsars to follow the mixing of matter within the cocoon as it evolves. Using this data, we compute the radiation signatures of cocoons from different progenitor stars with varying cocoon mixing. These simulations will enable us to understand the luminosity and radiation properties of the cocoon. When compared to observations, our calculations may put constraints on the progenitor stars structure that produces gamma-ray bursts.

352.10 – Pulse Decomposition of Gamma-Ray Burst Light Curves Using Bayesian Droplets

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1. Cornell University, Ithaca, NY, United States. 2. College of Charleston, Charleston, SC, United States. 3. Duke University, Durham, NC, United States.

We describe ongoing work on modeling the spectro-temporal behavior of prompt gamma ray emission from GRBs by modeling gamma ray count and event data with a population of pulses, with the pulses drawn from one or more families of single-pulse kernels. Our approach is built on a multilevel nonparametric probabilistic framework we have dubbed "Bayesian droplets," and offers several important advances over previous pulse decomposition approaches: (1) It works in the pulse-confusion regime, quantifying uncertainty in the number, locations, and shapes of pulses, even when there is strong overlap. (2) It can self-consistently model pulse behavior across multiple spectral bands. (3) It readily handles a variety of spatio-temporal kernel shapes. (4) It provides an explicit, quantitative description of a burst as a population of pulses, enabling direct modeling and estimation of the pulse population distribution. We describe the framework and present analyses of prototypical simple and complex GRB light curves. This work has been supported by the NASA Applied Information Systems Research Program.

352.11 – Template Reproduction of GRB Pulse Light Curves

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A study of well-isolated pulses in gamma ray burst light curves indicates that simple models having smooth and monotonic pulse rises and decays are inadequate. Departures from the Norris et al. (2005) pulse shape are in the form of a wave-like

pre-peak residual that is mirrored and stretched following the peak. Pulse shape departures are present in GRB pulses of all durations, but placement of the departures relative to pulse peaks correlates with asymmetry. This establishes an additional link between temporal structure and spectral evolution, as pulse asymmetry is related to initial hardness while pulse duration indicates the rate of hard-to-soft pulse evolution.

352.12 – Extrapolating Dust Composition from GRB SEDs: A Cautionary Tale

Adria C. Updike[1], Robert L. Jacobson[1]
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Many groups have drawn conclusions about dust composition and particle size distribution in gamma ray burst host galaxies from spectral energy distributions with limited data coverage. Using careful statistical analysis and a large set of GRB SEDs from the literature, we show that only a small percentage of the SEDs, when carefully calibrated, can be used to draw potentially useful conclusions as to the nature of dust in the host galaxy. A few of the particularly well-constrained GRBs are highlighted in this study, as is the dust model used to extrapolate the dust composition.

352.13 – Missing High-Energy Gamma-ray Afterglows of Gamma-ray Bursts

Carrie Holt[1,2], Judith L. Racusin[3], Daniel Kocevski[4]
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Contributing teams: Fermi Large Area Telescope Collaboration

The largest explosions in the Universe, gamma-ray bursts (GRBs), are short-lived signatures of a rare type of end stage stellar evolution. We study the X-ray and gamma-ray emission with the Swift and Fermi observatories. High energy gamma-ray (>100 MeV) emission from these objects is rare, only present in ~8% of GRBs. We investigate whether or not there are bursts in the Swift sample that should have been detectable by Fermi-LAT, assuming the same emission component. By using the well-studied Swift X-ray afterglows, we extrapolate from the soft X-ray energy range (0.3 keV-10 keV) to the LAT energy range (100 MeV-100 GeV), to search for bursts which should have had high-energy afterglows, but must have breaks or cutoffs in their spectra. We compare the extrapolated gamma-ray fluxes to upper limits measured while the GRBs were in the LAT field of view, and find candidates for cutoff spectra requiring full broadband modeling. By characterizing the missing LAT afterglows, we can gain a better understanding of the emission mechanism, environment, and microphysical parameters.

352.14 – The Nature of the Most Extreme Cosmic Explosions: Broadband Studies of Fermi LAT GRB Afterglows

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In the five years since its launch, the Fermi Large Area Telescope (LAT) has revealed a population of gamma-ray bursts (GRBs) that are among the most energetic explosions ever observed. While typical GRB afterglows are observed from radio to X-rays, afterglows of Fermi LAT GRBs are detected up to GeV energies, challenging our understanding of GRB emission mechanisms and central engines. There are now a significant number of LAT-detected GRBs with multi-wavelength afterglow data and measured redshifts that allow us to investigate potential correlations between this high-energy (> 100 MeV) emission and the afterglow parameters and determine if any particular conditions (e.g., weak magnetic field or low density medium) must be met by the progenitor system in order to generate the bright GeV emission. We developed an afterglow fitting code to model and fit the broadband afterglow data in counts space, allowing us to directly test the model predictions on the observed data. The uncertainties in our results were derived using a Markov Chain Monte Carlo analysis, which allows us to uncover degeneracies between the physical parameters of the explosion. Here we present the preliminary results of our study of the population of Fermi LAT-detected GRBs.

353 – Planetary Nebulae, Supernova Remnants
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

353.01 – XMM-Newton X-ray studies of Supernova Remnants in the Large Magellanic Cloud

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Contributing teams: High Energy Group at Max Planck Institute for Extraterrestrial Physics

The Large Magellanic Cloud (LMC) hosts a large sample of supernova remnants (SNRs). The LMC's proximity (~50 kpc) and lack of strong foreground ISM absorption make it an ideal target for studying these significant objects. SNRs are important to study, as they contribute to the energy balance, chemical enrichment, and mixing of the interstellar medium (Maggi et al. 2012). As contribution to a full X-ray survey of the LMC undertaken by Maggi & Haberl (Max Planck Institute for Extraterrestrial Physics), using the modern X-ray observatory XMM-Newton, we studied a few specific SNRs located in this galaxy. New X-ray data on SNRs J0513-6912, J0518-6939, J0527-6912, and J0530-7008, obtained by XMM-Newton are presented; processed and fitted using various Linux scripts and the X-ray spectral fitting program XSPEC. Using these data, the physical properties of the progenitors of the supernovae are determined for each of the surveyed objects. This research is supported by the Villanova Undergraduate Research Fellows (VURF), the Max Planck Society (MPG), and the DAAD-RISE scholarship program. We also acknowledge support from NSF/RUI Grant AST 1009903 to Villanova University.

353.02 – XMM-Newton Large Program of SN1006

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Contributing teams: XMM-Newton LP team of SN1006

We present results from spatially resolved spectroscopy analysis of the historical supernova remnant (SNR) SN1006 based on our XMM-Newton large program with total effective exposure times of 683, 710, and 439 ks from MOS-1, MOS-2, and PN. We analyze the spectra extracted from 3596 tessellated regions to map out the physical parameters, such as the electron number density, ionization parameter, ionization time, power law photon index of the synchrotron emission, normalization ratio of the nonthermal and thermal components, and abundance ratios of Ne/O, Mg/O, and Si/O. We also construct equivalent width (EW) maps of many emission lines based on either the linear interpolation method or the interpolated continuum from our spatially resolved spectroscopy analysis. The spatial distributions of physical parameters as revealed by the parameter maps or the EW maps are qualitatively consistent with the spectra extracted from larger (than the tessellated meshes) regions. We further discuss the origin of some residuals in the spectral fitting and the reliability of the parameter maps. In particular, the significant residuals at 0.7-0.75 keV is most likely the blueshifted component of the OVIII K-shell transitions, with the redshifted component sometimes detected at ~0.6 keV, and the line-of-sight velocity consistent with the expansion of the SNR shell measured from the multi-wavelength proper motions. We also find the SiXIII lines are significantly shifted to lower energy. We then study the azimuthal variation of the synchrotron spectral index and the cut-off frequency along the nonthermal filaments. The azimuthal dependence of these parameters provide strong constraints on the cosmic ray (CR) acceleration mechanism. In order to explain the spatial distribution of the thermal plasma properties, as well as the multi-wavelength observations (in particular, the Hα image and UV/optical absorption lines), we present a geometric model assuming the SN explored in a low density bubble surrounded by an equatorial disk. We conclude that the explosion of the progenitor of SN1006 is not necessarily asymmetric, but the asymmetric distribution of the ISM may be enough to produce the observed multi-wavelength features.

353.03 – Shock and Awe: Measuring the Expansion of the Shock Front of Supernova Remnant SN1006

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We have determined the expansion of the supernova remnant (SNR) of SN1006 over a seven-year period, using data collected in 2003 and 2010. The data was calibrated and imaged using Miriad and CASA programming before we stacked the two images to accurately assess the expansion rate. Our data was collected from the Very Large Array (VLA) in New Mexico and Australian Telescope Compact Array (ATCA). The 2003 epoch observations were conducted at the ATCA and the VLA. The 2010 epoch observations were conducted only at the ATCA. We processed the data using the Miriad and CASA software packages, which allowed us to perform calibration and imaging of radio interferometer visibility data. We deconvolved the raw images using CLEAN and MAXEN (maximum entropy deconvolution) to remove spurious side lobes, resulting in epoch images with a synthesized beamwidth of 6.0 arcseconds per beam. We used the 2010 image as a template to align the 2003 image and to match resolution. A difference image formed from the two epoch images reveals an obvious expansion of the

SNR. We measured the expansion rate at nine points along the shell of the remnant. We found that the expansion rate varied across the remnant's shell. The greatest amount of expansion measured was 5.71 arcseconds over seven years, which for a distance of 2.2 kpc, has the remnant moving at 8,500 km/s. The average expansion measured across the shell was 4.25 arcseconds over seven years.

353.04 – Spatio-temporal Spectral Variability in Cas A

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We have analyzed Chandra archival data of Cas A Supernova Remnant to identify regions with large spectral abnormalities and variability over the last decade. We use 8 ACIS-S observations spanning the years 2000 to 2012. We compute spectral hardness ratios in the soft/medium and medium/hard CSC bands over spatial scales corresponding to binning by 4, 8, 16, 32, and 64. We reduce the data and apply the latest calibration using the CIAO tool chandra_repro. We account for exposure variations using exposure maps and compute photon fluxes using the CIAO tool fluximage. We then renormalize the color light curves at each pixel and flag large departures from the norm by comparing with the observed spread in the renormalized color light curves. This allows regions with different intrinsic spectral properties to be compared. We flag deviations of >3? from the renormalized mean at each epoch, and combine all such pixels to form a map of interesting regions in the remnant. We also identify pixels which have intrinsically abnormal hardness ratios at each epoch. We show that there exist many sites on Cas A where abnormal variations in the spectrum exist. Specifically, we find that many of the identified regions coincide with prominent features of the SNR, such as the edge of the remnant, the central compact object, and numerous knots. In addition, we find various other locations (~1000) where there is indication of an atypical spectral signature. The full region lists, along with analysis scripts and the figures and tables shown in this poster, are stored on the Harvard Dataverse Network, at http://dx.doi.org/10.7910/DVN1/22634 YN thanks ABRHS and Young Einsteins Science Club for support and guidance. VK and DP acknowledge support during this project from the Chandra X-Ray Center.

353.05 – Using Low Frequency Radio Absorption to Measure the Density and Mass of Unshocked Ejecta in Cassiopeia A

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We have used Very Large Array observations of Cassiopeia A at low frequencies (74, 330, 1285 MHz) to determine the mass and electron density of the unshocked ejecta. The cold, ionized ejecta manifest themselves through free-free absorption, which is tied to optical depth and emission measure using assumptions about the distribution of the radio emission along the line-of-sight. The emission measure is then used to calculate density and mass for the unshocked ejecta. We estimate an electron density of 4.2 per cubic centimeter and a total mass of 0.39 solar masses for the unshocked ejecta with about a factor of two uncertainty.

353.06 – Using Rotation Measure Synthesis to Study Shocks in Cassiopeia A

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We observed Cassiopeia A with the Very Large Array between 2-4 GHz in the B, C, and D configurations to study the polarization structure in the vicinity of the shocks. We will use rotation measure synthesis to isolate the magnetic field structures that can help determine which turbulent processes play a dominant role in amplifying the magnetic fields. In addition, we will compare the radio polarization structures to X-ray images in order to determine if conditions are suitable at the reverse shock to produce X-ray synchrotron emission.

353.07 – Herschel Constraints on the Mass of Shocked Dust in the O-rich Supernova Remnant G292.0+1.8

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We present PACS and SPIRE images of the Galactic SNR G292.0+1.8, acquired during the Cycle 2 GO program of the Herschel Space Telescope. The goal of these images was to search for newly formed ejecta dust in this O-rich SNR, as well as study dust heating and destruction on small scales behind shock. Dust emission from radiatively shocked O-rich ejecta is clearly detected in the PACS blue band image (60-85 microns) enabled in large part by the excellent sensitivity and spatial resolution of PACS at those wavelengths. This is firm evidence of cold, freshly synthesized dust in the ejecta of G292.0+1.8. The outer blast wave shock is also detected in the PACS blue band, as well as the belt of circumstellar material associated with shocked circumstellar wind from the stellar progenitor. We have placed upper limits on emission at longer wavelengths in the red-band PACS images (130-210 microns), as well as SPIRE images between 250 microns and 500 microns. Using flux limits from both the PACS and longer wavelength SPIRE images, as well as existing IRS mapping spectra of G292, we create a broad-band spectrum of the SNR in the 14-500 micron range, placing global constraints on the mass and temperature of shocked circumstellar and ejecta dust in G292.0+1.8.

353.08 – X-Ray Kinematics of the Galactic Core-Collapse Supernova Remnant G292.0+1.8

Sangwook Park[1], Jayant Bhalerao[1], Daniel Dewey[2], John P. Hughes[3], Patrick O. Slane[4], David N. Burrows[5], Jae-joon Lee[7], Koji Mori[6]

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We report on the results from the preliminary analysis of our 120 ks Chandra HETGS observation of the Galactic core-collapse supernova remnant (SNR) G292.0+1.8. To probe the 3D distribution of the metal-rich ejecta features, we measured Doppler shifts in emission lines from ejecta knots projected at a range of distances from the SNR center using high resolution HETGS spectroscopy. We estimate radial velocities of v ~ -2200 - +1300 km/s. Their overall distribution in the velocity-position space suggests an expanding shell of ejecta. We qualitatively estimate the locations of the reverse shock and contact discontinuity based on this distribution. The reverse shock in G292.0+1.8 appears to be at ~130" from the SNR center, which is close to the outer boundary of the radio pulsar wind nebula.

353.09 – A Hubble Space Telescope Measurement of the Forward Shock Velocity of the Supernova Remnant 0509−67.5 in the Large Magellanic Cloud

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Using two Hubble Space Telescope narrow-band Hα images of the supernova remnant 0509-67.5 taken ~1 year apart we determine the proper motion expansion of the remnant's forward shock. The first epoch image was obtained with the Advanced Camera for Surveys, while the second epoch was taken with the Wide Field Planetary Camera 2. The supernova remnant 0509-67.5 is a rare specimen in that it is a Balmer-dominated remnant, and its light echoes have shown spectra showing it to be of Ia origin and likely analogous to a SN1991T-type explosion (Rest et al. 2008). After examining the expansion velocity versus position angle we find the remnant's forward shock to have a velocity of 6,500±200 km/s. We also examine proper motions of the forward shock where deep optical spectroscopy had been previously obtained by Helder et al. 2010 in the north-east and south-west of the remnant, and directly compare the width (FWHM) (3,900±900 km/s) of the broad Hα emission line to the forward shock velocity. Comparing these values, along with the measured broad-to-narrow ratio of 0.08±0.02 (Helder et al. 2010), allows us to constrain the degree of equilibration, β, between shocked electrons and protons (Te,shocked/Tp,shocked) in the NE to be <0.03. We employ 1-D hydrodynamical simulations to constrain the density of the ambient medium and the age of the remnant. We use three different initial ejecta density profiles (power law profiles with indices of n=7 and n=4 plus an exponential profile) and we also vary the effective equation of state of the shocked interstellar material from a monatomic gas with ?=5/3 to an effective ?=1.1 to approximate the effect of efficient cosmic ray acceleration at the shock front. According to our analysis the remnant's age is between 230 and 390 years and it is expanding into an ambient medium with a density in the range 0.04-0.38 cm^{-3}.

353.10 – Near IR Spectroscopic Analysis of Molecular Hydrogen in the Dumbbell Nebula (NGC 6853)

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We present Ks band (1.98-2.32 μm) spectroscopic analysis of several distinct regions in the Dumbbell Nebula specifically focusing on molecular hydrogen (H_2) ro-vibrational lines which dominate the near-IR spectrum. Four H_2 lines are observed;

corresponding to the H$_2$ transitions v = 1 ? 0 S(0), S(1), S(2) and v = 2 ? 1 S(1). In order to determine the mechanisms behind the H$_2$ emission; specifically between PDR and shock excitation, line ratios are used to estimate both rotational and vibrational excitation temperatures of the H$_2$. Several morphologically and positionally distinct regions of H$_2$ emission are observed and compared in order to determine any differences between excitation mechanisms within the nebula. In order to build a more complete model of planetary nebulae (PNe), all observations are compared to previous H$_2$ studies of other PNe – specifically the Helix and Ring nebulae.

353.11 – Using [FeII] to Search for Supernova Remnants in NGC 6946

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Supernovae and supernova remnants (SNRs) play an important role in the evolution of the interstellar medium of their host galaxies. A crucial part in gaining a better understanding of this role is in obtaining a large sample of such objects and studying how their properties relate to their physical environment. Usually, SNRs are identified at optical wavelengths as emission nebulae with high [SII]:Hα flux ratios compared to HII regions. However, in the IR, shock models indicate and observations show that SNRs emit strongly in [Fe II] at 1.64 µm. Here we report on an attempt to use the [Fe II] 1.64 µm line to search for SNRs in the nearby starburst galaxy NGC 6946. For this study we have used the WIYN High Resolution Infrared Camera (WHIRC) on the WIYN 3.5m telescope to image NGC 6946 in broad bands J and H and narrow bands [FeII], [FeII]-4500, Paβ and Paβ-4500 (where -4500 indicates an offset ~4500 km s-1 from the named filter). We processed the images to create a mosaic image of NGC 6946 in each of the six filters and visually searched these mosaics to find potential supernova remnants using the criteria that candidates should show significant [FeII] emission, but little of no emission in the other filters. We have identified 47 supernova remnant candidates (SNRcs). Only one of these objects is coincident with an optically selected SNR. The [FeII] fluxes range from 1.5e-16 to 4.2e-15 erg s-1 cm-2. These fluxes are at the highest end of previously published extragalactic SNR [FeII] fluxes, which suggests there is a much larger population of SNRs in NGC 6946 below the detection threshold of our data. All of the candidates now need to be confirmed spectroscopically. However, the fact that we detect as many objects as we did, suggests that [FeII] can be used as an effective search tool to find extragalactic SNRs.

353.12 – The Young Core-Collapse Supernova Remnant G11.2-0.3: An Asymmetric Circumstellar Medium and a Variable Pulsar Wind Nebula

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G11.2-0.3 is a young supernova remnant (SNR) that has been suggested to be associated with a historical supernova of 386 AD. In addition to a bright radio and X-ray shell, it contains a pulsar wind nebula (PWN) and a 65 ms pulsar. We present first results from new deep (about 400 ks in duration) Chandra observations from 2013 May and September. Ahead of the main shell, there are a number of outlying X-ray protrusions surrounded by bow shocks, presumably produced by dense ejecta knots. Pronounced spectral variations are seen in thermal X-ray spectra of the main shell, indicating the presence of shocks with a wide range in shock speeds and large spatial variations in intervening absorption. A band of soft X-ray emission is clearly seen at the remnant's center. We interpret this band as a result of the interaction of supernova ejecta with the strongly asymmetric wind produced by a red supergiant SN progenitor shortly before its explosion. We study interstellar absorption in the central region of the remnant, finding high absorption everywhere. This rules out the association of G11.2-0.3 with SN 386. The PWN is dominated by a bright "jet" whose spatial morphology is markedly different between our May and September observations.

353.13 – High-Resolution Near-Infrared Spectra of the Proto-Planetary Nebula, MWC 922

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Contributing teams: The SDSS-III/APOGEE Team

The detailed abundance and morphology properties of the diverse objects collectively labeled 'B[e] stars' remains uncertain. As part of a program targeting known emission line objects in order to compare to new emission-line sources discovered in the SDSS-III/APOGEE survey, the unclassified B[e] star MWC 922, a proto-planetary nebula also known as the Red Square Nebula, was observed. Our high-resolution (R ~ 22,500) H-band spectra from APOGEE reveal a number of metal lines,

including low-ionization species of Fe, C, Si, and Co, although our current line list is insufficient to identify all of the emission lines observed. At least one Diffuse Interstellar Band (DIB) is present, consistent with previously observed high dust and PAH column densities toward this source. Whereas the Hydrogen recombination lines and the allowed metal lines are all fairly broad (~100s km/s), the [Fe II] emission features have two components, consisting of a broad emission line with a narrow emission line superposed. We identify a large number of the observed lines and attribute the variations in line width to specific geometrical features in the nebula. This approach provides new insight into the excitation mechanisms for the two-component model that has been proposed for similar proto-planetary nebulae.

353.14 – Chandra observations of SNR RCW 103

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RCW103 is one of a class of young supernova remnants with no detected emission from metal-rich ejecta. Multi-wavelength observations also reveal indications that RCW103 is interacting with a neighboring molecular cloud. We present an X-ray analysis of RCW103, incorporating the most recent Chandra observations for a combined exposure time of ~110 ks. We search for the presence of metal-rich ejecta and provide spectral fits to various features, including several prominent protrusions at the edge of the remnant. We also investigate a distinct strongly absorbed region in the northeast quadrant of the remnant.

353.15 – X-ray Measurements of Tycho Supernova Remnant's Dynamics

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In the following work we present X-ray dynamics measurements of the Tycho supernova remnant G120.1+01.4. We compare observations and spectra from 2005 and 2009 archived in XMM Newton Science Archive in order to determine differences caused by collision with surrounding interstellar medium (ISM) as well as by remnant's own expansion. We have calculated the azimuthal expansion of remnant's edges to vary from 0.194 arcsec/yr to 0.438 arcsec/yr, while the highest values are found to have the azimuth of about 60° in the south-east and the lowest expansion overall is estimated on the north. Comparison of fluxes has shown that the highest estimated energy gain of 3.1 times was measured in reverse shock region around the azimuth of 300° in the energy range from 6.1 keV to 8 keV, whereas the highest energy loss was found to be in the same energy range in forward shock region with the azimuth of approximately 70° reaching 2.4 times lower energy compared with the values from 2005. We have also defined the most abundant heavy elements within energy scale from 200 eV to 8 keV, which are identified through spectral lines to be Fe XVIII (0.849 keV), Mg XI and XII (1.34 keV, 1.46 keV), Si XIII (1.83 keV), S XV (2.41 keV, 2.86 keV) and Ca XIX (3.84 keV).

353.16 – Understanding the Balmer Bubble in the Vela Supernova Remnant

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We present imaging and spectroscopic data and analysis of the Balmer-dominated filament that is ahead of the eastern edge of the radiative shock of Bullet C in the Vela Supernova Remnant. This filament was discovered in 2002 by Carlin & Smith(2002), and was suggested to be a non-radiative shock. Images of the filament were taken using Hα and R band filters on the SMARTS 0.9m telescope at CTIO. These images were then compared to images taken in 2006 using the MOSAIC II imager on the Blanco Telescope at CTIO, in an attempt to detect proper motion of the filament. Comparison over the 7 year baseline failed to show proper motion of the filament. From this result, we are able to place an upper limit of ~270 km/s on the velocity of the Balmer-dominated filament. We also obtained moderate resolution spectra of the Balmer-dominated filament and the radiative shock using the Goodman Spectrograph at SOAR Telescope. Spectroscopic analysis of the Balmer-dominated filament failed to detect a broad component of the Hα emission line, which would be expected for a high velocity non-radiative shock.

353.17 – Fermi-LAT Observations of Supernova Remnants Interacting with Molecular Clouds

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Contributing teams: Fermi-LAT Collaboration

Studying gamma rays from supernova remnants interacting with molecular clouds provides a promising route to explore the

connection between cosmic rays and supernova remnants, allowing us to assess the mechanisms of particle acceleration and diffusion from the remnant. Energy dependent escape of accelerated cosmic rays from the forward shock of a remnant can lead to illumination of nearby molecular clouds through proton-proton interactions. Probing the gamma rays emitted via neutral pion decay provides a means for tracking the elusive cosmic ray protons as they escape their source, and a method to constrain the local diffusion coefficient around supernova remnants. Using 5 years of Fermi-LAT data, we search the vicinity of several supernova remnants for non-identified GeV emission and correlate the results with archival radio CO line data to identify potential sites of interaction. Here we present the status of this study and discuss the possibility of constraining the diffusion coefficient near supernova remnants.

353.18 – Investigating Possible Departures from Maxwellian Energy Distributions in Nebulae using High-Resolution Emission Line Spectra

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The derivation of ionic abundance ratios from collisionally excited emission lines in gaseous nebulae requires knowledge of the physical state of the gas, particularly the electron kinetic temperature, T_e, to which the resulting abundances are highly sensitive. A long-standing problem in nebular analyses has been pervasive discrepancies among values of T_e obtained from different diagnostic ratios for a single nebula. Recently, Nicholls et al. (2012, ApJ, 752, 148) have suggested that the nebular electrons may not obey an equilibrium Maxwell-Boltzmann (M-B) energy distribution, but instead follow a "? distribution" seen in many solar system plasmas, a family of distributions for which the M-B distribution is the limiting case where ? ? ?. The high-energy tail of supra-thermal electrons in ? distributions have a disproportionate effect on strongly energy dependent quantities, such as T_e diagnostics, for even modest departures from M-B distributions. We apply prescriptions given by Nicholls et al. (2013, ApJS, 207, 21) to high-resolution (R=36,700) optical spectra of 10 planetary nebulae obtained with the 2d-coudé echelle spectrograph on the 2.7 m Harlan J. Smith Telescope at McDonald Observatory. The advantages of these data include their broad spectral coverage and sufficiently high spectral resolution to separate blended lines and assess possible atmospheric absorption issues. The line fluxes were obtained using ROBOSPECT, an automated spectral line measurement package developed by Waters & Hollek (2013, PASP, 125, 1164). We solve both for T_e under the assumption of M-B distributions, and the parameters of ? distributions consistent with the data. Our goal is to test whether the ? distribution hypothesis provides a better fit to the observed line ratios. Finally, we discuss effects on the derived ionic abundances under this alternate description of the particle energy distributions. This research was supported by NSF grant AST 0708245 and the John W. Cox Endowment for Advanced Studies in Astronomy at the University of Texas at Austin.

353.19 – GAMMA-RAY EMISSION FROM SUPERNOVA REMNANT INTERACTION WITH MOLECULAR CLUMPS

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Observations of the middle-aged supernova remnants IC 443, W28, and W51C indicate that the brightnesses at GeV and TeV energies are correlated with each other and with regions of molecular clump interaction, but not with the radio synchrotron brightness. We suggest that the radio emission is primarily associated with a radiative shell in the interclump medium of a molecular cloud, while the Gamma-ray emission is primarily associated with the interaction of the radiative shell with molecular clumps. The shell interaction produces a high pressure region, so that the Gamma-ray luminosity can be approximately reproduced even if shock acceleration of particles is not efficient, provided that energetic particles are trapped in the cooling shell. In addition, the GeV through TeV emission can be produced in the interaction region if the trapping occurs to sufficiently high energies. Alternatively, diffusive acceleration may be efficient; in this case the observed GeV emission can be approximately reproduced, but not the TeV emission.

353.20 – Protrusions Beyond the Blast Waves of Young Type Ia Supernova Remnants: Hydrodynamic Instabilities or Ejecta Bullets?

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High resolution imaging of two young Type Ia supernova remnants (SNRs), Tycho and SN 1006, has revealed several morphological features which have resisted explanation with numerical simulations. One such feature is the presence of shocked ejecta blobs protruding beyond the mean forward shock radius. Two current theories explain the presence of such ejecta: highly dense ejecta shrapnel produced in the explosion penetrating the forward shock, or plumes generated by hydrodynamic instabilities long after the initial explosion. We investigate the shrapnel theory through hydrodynamic simulations in 2D and 3D of the evolution of dense ejecta clumps embedded in an exponential density profile, appropriate for Type Ia supernovae. We use high-resolution 2D simulations to identify relevant clump parameters which we investigate further in 3D. In contradiction to some former work, we find that sufficiently resolved clumps in 2D models shatter upon

collision with the forward shock, yielding new protrusion features. In both 2D and 3D, shrapnel is capable of penetrating the forward shock, but the resultant protrusions in 3D simulations vary significantly from those in similar 2D runs, implying 2D simulations may not be an accurate method of investigating the shrapnel theory. We compare the our simulations with Chandra observations of projections seen in Tycho and SN 1006. This work was performed as part of NC State University's Undergraduate Research in Computational Astrophysics (URCA) program, an REU program supported by the National Science Foundation through award AST-1032736.

353.21 – Analysis of Shock Interactions and Supernova Morphology from Molecular Emission Around Young Supernova Remnants

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We have observed the supernova remnant Cassiopeia A (Cas A) in the mid-infrared from 10-40 microns with the Spitzer Space Telescope and at millimeter wavelengths in 12CO and 13CO J=2-1 (230 and 220 GHz) with the Heinrich Hertz Submillimeter Telescope (HHSMT). Broadened (6 - 10 km/s) CO emission in the millimeter indicates that some molecular clouds towards the line of sight of the Cas A shock front have been shock broadened by ejecta from the remnant. The IR spectra demonstrate high-velocity emission along the northern shock front of the remnant coincident with bright radio continuum emission. These features trace a direct interaction with the Cas A shock front. Furthermore, some of the broadened molecular emission extends 1 - 2 arcminutes beyond the furthest extent of the SNR shock front. We infer from the proximity to the remnant as well as the positions of broadened CO emission that this material is accelerated by ejecta with velocity significantly larger than the observed free-expansion velocity of the Cas A shock front. This observation is consistent with a bipolar outflow as well as fast-moving ejecta pistons inferred in the Cas A remnant, in particular along the southwest to northeast axis of the remnant. We extend this type of analysis to other young, galactic supernova remnants in order to place constraints on the morphology and shock interactions during supernova events.

353.22 – Electron Heating, Magnetic Field Amplification, and Cosmic Ray Precursor Length at Supernova Remnant Shocks

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We investigate the observability, by direct and indirect means, of a shock precursor arising from magnetic field amplification by cosmic rays. We estimate the depth of such a precursor under conditions of nonresonant amplification, which provides magnetic field strengths comparable to those inferred for supernova remnants. Magnetic field generation occurs as the streaming cosmic rays induce a plasma return current, and may be quenched either by nonresonant or resonant channels. In the former case, the cosmic rays become magnetized and amplification saturates at higher magnetic fields. The precursor can extend out to $10^{17} - 10^{18}$ cm and is potentially resolvable in Galactic supernova remnants. If the saturation occurs instead by resonant channels, the cosmic rays are scattered by turbulence and the precursor length will likely be too small to be resolvable with current instruments. The dependence of precursor length on shock velocity has implications for electron heating. In the case of resonant saturation, this dependence is similar to that in the more familiar resonantly generated shock precursor, which when expressed in terms of the cosmic ray diffusion coefficient ? and shock velocity v_s is ? /v_s. In the nonresonantly saturated case, the precursor length declines less quickly with increasing v_s. Where precursor length proportional to $1/v\_s$ gives constant electron heating, as observed for instance by Ghavamian et al. and van Adelsberg et al., this increased precursor length would be expected to lead to higher electron temperatures at faster supernova remnant shocks than studied by these previous works as an indirect observation of the shock precursor. Existing results and new data analysis of SN 1006 and Cas A suggests some observational support for this idea. Work supported by NASA ADAP program and by basic research funds of the Office of Naval Research.

353.23 – Electron-Ion Equilibrium and Shock Precursors in the Northeast Limb of The Cygnus Loop

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We present an observational study using high-resolution echelle spectroscopy of collisionless shocks in the Cygnus Loop supernova remnant. Measured H alpha line profiles constrain pre-shock heating processes resulting in narrow component broadening, cosmic-ray acceleration, and electron-proton equilibration. The shocks produce faint H alpha emission line profiles, which are characterized by narrow and broad components. The narrow component is representative of the pre-shock conditions, while the broad component is produced after charge transfer between neutrals entering the shock and protons in the post-shock gas, thus reflecting the properties of the post-shock gas. We observe a diffuse H alpha region extending about

2.5 arcmin ahead of the shock with line width about 29 km/s, while the H alpha profile of the shock itself consists of a broader than expected narrow (36 km\s) and a broad (250 km/s) component. The observed diffuse emission arises in a photoionization precursor heated to about 18,000 K by He I and He II emission from the shock, with additional narrow component broadening originating from a thin cosmic-ray precursor. Broad to narrow component intensity ratios of about 1.0 imply full electron-proton temperature equilibration (equal ion and electron temperatures) in the post-shock region. Broad component line widths indicate shock velocities of about 400 km/s. Combining the shock velocities with proper motions suggests the distance to the Cygnus Loop is about 890 pc, significantly greater than the generally accepted upper limit of 637 pc. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution. This work was partially supported by the grant HST-60-12885 to the Smithsonian Institution.

353.24 – 3D Simulations of Supernova Remnants from Type Ia Supernova Models

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Type Ia supernovae (SNe) originate from thermonuclear explosions of white dwarfs. A great deal is still unknown about the explosion mechanisms, particularly the degree of asymmetry. However, Type Ia supernova remnants (SNRs) can bear the imprint of asymmetry long after the explosion. A SNR of interest is G1.9+0.3, the youngest Galactic SNR, which demonstrates an unusual spatial distribution of elements in the ejecta. While its X-ray spectrum is dominated by synchrotron emission, spectral lines of highly ionized Si, S, and Fe are seen in a few locations, with Fe near the edge of the remnant and with strongly varying Fe/Si ratios. An asymmetric explosion within the white dwarf progenitor may be necessary to explain these unusual features of G1.9+0.3, in particular the shocked Fe at large radii. We use the VH-1 hydrodynamics code to evolve initial Type Ia explosion models in 1, 2, and 3 dimensions at an age of 100 seconds provided by other researchers to study asymmetry, the ignition properties, and the nucleosynthesis resulting from these explosions. We follow the evolution of these models interacting with a uniform external medium to a few hundred years in age. We find the abundance and location of ejecta elements from our models to be inconsistent with the observations of G1.9+0.3; while our models show asymmetric element distributions, we find no tendency for iron-group elements to be found beyond intermediate-mass elements, or for significant iron to be reverse-shocked at all at the age of G1.9+0.3. We compare the amounts of shocked iron-group and intermediate-mass elements as a function of time in the different models. Some new kind of explosion asymmetry may be required to explain G1.9+0.3. This work was performed as part of NC State University's Undergraduate Research in Computational Astrophysics (URCA) program, an REU program supported by the National Science Foundation through award AST-1032736.

353.25 – Are Planetary Nebulae in Globular Clusters a Binary Phenomenon?

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It is believed that PNe can only form in globular clusters if the progenitor had been a close binary. We test this hypothesis by re-measuring the masses of all four PN central stars in the Galactic globular clusters. We obtained HST imaging data in V, I, [OIII], and Hα for JaFu 1 in Pal 6, the only PN in a globular cluster without HST observations, to determine the central star magnitudes and colors, and to examine its nebular morphology. We also obtained deep [OIII] images of IRAS 18333-2357, the PN in M22, to improve its morphological classification. We combine these data with archival HST spectra and images for K648 (aka, Ps 1) in M15 and for JaFu 2 in NGC 6441 to estimate the central star masses for all four PN. We use post-AGB tracks to derive masses, after re-evaluating the distances and temperatures, and hence luminosities. Three of the stars have masses of ~0.55 Msun (uncertainties of 0.01-0.02), only slightly higher than the WD masses found in clusters (~0.53 Msun) indicating that they may be descendants of single stars, but their morphology suggests otherwise. K648, though, has a mass ~0.58 Msun suggesting that mass augmentation has occurred, thereby arguing more strongly for a binary interaction in the evolutionary history of these stars.

353.26 – Post-Ejection Evolution of the Orbital Components in the Common Envelope Phase

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Theoretical orbital period distributions of planetary nebulae containing binary cores calculated using reasonable prescriptions for the common envelope efficiency parameter, alpha, peak at orbital periods that are longer than observed. Possible resolutions to this discrepancy are suggested that involve further dynamical evolution of the embedded binary within the common envelope after the material outside of the orbit has been ejected. These scenarios are investigated via population synthesis calculations of the orbital period distribution in planetary nebulae containing binary cores.

353.27 – The Chandra Planetary Nebula Survey (ChanPlaNS): Results from Cycle 14

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Contributing teams: ChanPlaNS Team

The Chandra Planetary Nebula Survey (ChanPlaNS) is the first comprehensive X-ray survey of PNe in the solar neighborhood (within ~1.5 kpc). ChanPlaNS began with a combined Cycle 12 and archive Chandra survey of 35 PNe, resulting in an overall ~70% X-ray detection rate. The survey is yielding such fundamental, new results as the frequency of appearance and range of X-ray spectral characteristics of X-ray-emitting PN central stars and the evolutionary timescales of wind-shock-heated bubbles within PNe. ChanPlaNS is continuing via a Chandra Cycle 14 Large Program targeting all (24) remaining known compact (radius <= 0.4 pc), young PNe that lie within ~1.5 kpc. We will present preliminary results from the latest (Cycle 14) ChanPlaNS observations, including first-time X-ray detections of hot bubbles within NGC 1501, 6369, and 3918. This research is supported via award number GO3-14019A to RIT issued by the Chandra X-ray Observatory Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of NASA under contract NAS803060.

353.28 – Chemical Abundances of Compact Planetary Nebulae in the Galactic Disk

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We present preliminary results from an optical spectroscopic survey of compact planetary nebulae (PNe) in the Galactic disk. This is an ongoing optical+infrared spectral survey of 150 compact PNe to build a complete sample of PN chemical abundances in the Galactic disk. The optical spectra will be combined with *Spitzer* spectra of IR collisional lines to improve abundance constraints. Our targets are mostly young PNe, which are well suited for studying the impact of metallicity and dust on PN morphology. Our main objectives are: (1) to constrain stellar evolution models, particularly the metallicity-dependent onset of hot-bottom burning; (2) to quantify the contribution of low- to intermediate-mass stars to chemical enrichment; and (3) to improve the ionization correction factors for Ne, O, S, and Ar that we have observed in the IR. We will also compare these findings to our optical+IR Magellanic Cloud PN abundances to better understand the influence of environment metallicity on stellar chemical yields.

353.29 – The Chemical Diversity of Planetary Nebulae

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The metallicity of the progenitor star of a planetary nebula (PN) can be inferred from measurements of elements whose abundances are unaffected by nucleosynthesis during the star's evolution. In practice, nearly all of the observable elements that qualify, such as O, Ne, S, and Ar, are α species (built up by α-capture reactions). On the other hand, the total elemental abundances of the Fe-group nuclei are not directly measurable in ionized nebulae due to the highly refractory character of Fe and most other Fe-group elements. Although emission lines of several Fe ions are seen in many PNe, they generally indicate mildly to severely subsolar gas-phase abundances that are interpreted as the consequence of depletion into dust. The identification of a near-infrared emission line of Zn, the least refractory (by far) Fe-group element, by Dinerstein & Geballe (2001, ApJ, 562, 515) provided the first practical tracer of Fe/H in PNe. In this poster, we recap results to date from observations of Zn in 21 PNe from a range of Milky Way populations including the thin and thick disk and three Local Group dwarf galaxies. Combined with the results of Smith, Zijlstra, & Dinerstein (2013, MNRAS, submitted) for several objects in the Galactic Bulge, we find that PNe echo the abundance patterns of their parent populations: PNe with spatio-kinematic properties of Fe-poor stellar populations (e.g. the thick disk and bulge) tend to have subsolar zinc (<[Zn/H]> ? 0.6 dex) accompanied by elevated [O/Zn]. This conforms to the composition profile of the corresponding stars, if [Zn/H] and [O/Zn] can be taken as proxies for [Fe/H] and [α/Fe] respectively. Deducing the Fe/H metallicity of a PN from an α element alone is inadvisable, as a low-[Fe/H], high-[α/Fe] pattern is indistinguishable from one of solar [Fe/H] and [α/Fe]. To estimate [Fe/H] in a PN for which Zn measurements are unavailable or not feasible, the best approach is to measure an α species and scale by [α/Fe] typical of stars in the parent population. This research was supported by NSF grant 0708425.

354 – Supernovae Poster Session
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

354.01 – SweetSpot: A 3-year NOAO Survey to Observe 150 Type Ia Supernovae in the Near Infrared in the Nearby Hubble Flow

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SweetSpot is an NOAO Survey program from 2012B-2015A that will observe 150 Type Ia supernovae (SNe Ia) in the Hubble flow to obtain reliable near-infrared (NIR) luminosities free from peculiar-velocity confusion and the uncertainties of dust. A key part of the program is a focus on accurate calibration incorporating recently demonstrated techniques for characterization of telescope systems and the Earth's atmosphere. Our full SweetSpot program will (1) extend the NIR Hubble diagram past currently available samples; (2) quantitatively demonstrate the degree to which SNe Ia are robust standard candles in the NIR; (3) provide key insights about the color evolution and intrinsic properties of SNe Ia and their host galaxies; and (4) establish a well-calibrated low-redshift anchor for future NIR supernova surveys from JWST, Euclid, and WFIRST/NEW. By the end of the survey we will have measured the relative distance to a redshift of z~0.05 to 1%. Nearby Type Ia supernova (SN Ia) observations such as these will test the standard nature of SNe Ia in the rest-frame NIR, allow insight into the nature of dust, and provide a critical anchor for future cosmological SN Ia surveys at higher redshift. We will present the results from our pilot survey in 2011B and discuss our first year of full observations from 2012B-2013A.

354.02 – Automated classification of supernovae using low-resolution spectra and machine learning

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In order to succede, next generation time-domain surveys must automatically identify interesting targets for detailed follow-up that can be triggered before transient emission fades away. We evaluate the potential of machine learning tools for automated classification of supernovae based on low-resolution (R ~ 100) optical spectra. Several training and target supernova samples are simulated by drawing objects from SNID database and interpolating them to a random age. Classification accuracy is then evaluated for a range of S/N ratios and varying number of classes. The feature vector consists of 100 numbers corresponding to flux values at each wavelength normalized to continuum. Our results indicate that Support Vector Machines deliver good performance (90% or better) down to a modest S/N ~ 15 per pixel once sufficient training data set is available. We note a good prospect of this method for selecting young supernovae around 10 days before the peak light.

354.03 – Analysis of Nearby Supernova Factory Type Ia Spectra with SYNAPPS: Maximum-Light Sample

Caroline Sofiatti[1, 2], Rollin Thomas[1], Gregory S. Aldering[1], Stephen Bailey[1], Dan Birchall[1], Michael Childress[1], Hannah Fakhouri[1], Brian Hayden[1], Alex G. Kim[1], Jakob Nordin[1], Peter E. Nugent[1], Saul Perlmutter[1], David Rubin[1], Karl Runge[1], Clare Saunders[1], Nao Suzuki[1], Benjamin Weaver[1], Emmanuel Pecontal[3], Clement Buton[4], Yannick Copin[4], Nicolas Chotard[4], Emmanuel Gangler[4], Rui Pereira[4], Mickael Rigault[4], Gerard Smadja[4], Flora Cellier-Holzem[5], Arnaud Canto[5], Pierre Antilogus[5], Sebastien Bongard[5], Mathilde Fleury[5], Julien Guy[5], Reynald Pain[5], Juncheng Chen[6], Charling Tao[6], Ulrich Feindt[7], Peter Greskovic[7], Marek Kowalski[7], Simona Lombardo[7], Charles Baltay[8], David L. Rabinowitz[8]
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We present a preliminary study of absorption features in the maximum-light spectra of 68 Type Ia supernovae. These spectra are a subset of spectrophotometric time series obtained by the Nearby Supernovae Factory using the SuperNova Integral

Field Spectrograph (SNIFS). To extract ion signatures - strengths and velocities - from these absorption features we use the automated parameterized direct spectroscopic analysis code SYNAPPS. Trends in ion signatures as a function of spectroscopic sub-classification, photometric properties, and host galaxy stellar environment are considered. A new and experimental aspect of our approach is uncertainty quantification for SYNAPPS and calibration of its model inadequacy as a function of wavelength (for Type Ia supernovae near maximum light) using the Nearby Supernova Factory as a training sample. With further development and extension to other phases, this information could be used as a pre-processing step for SYNAPPS fitting, or it could be directly incorporated into SYNAPPS itself.

354.04 – Signatures of Explosion Asymmetry, Progenitor Density, and Magnetic Fields in Late-Time NIR Spectra of Type Ia SNe

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We will present several new model-motivated observational techniques for measuring physical properties in Type Ia SN explosions. Late-time NIR spectra of thermonuclear SNe show numerous strong emission features of [Co II], [Co III] and [Fe II] throughout the 0.8-2.5 micron region. The strong 1.64 micron [Fe II] feature often exhibits a flattened core line profile. Interpreted as an emission hole due to high-density electron capture in the early stages of burning, the width of this feature is sensitive to the central density of the progenitor. The slopes of the red and blue wings of this feature are sensitive to asymmetries in the explosion. Evolution of the width of the line feature probes the strength of magnetic fields in the expanding ejecta. Ratios between different iron lines often show unusual flux ratios not seen in normal nebular spectra and may be indicative of nebular resonances or other non-LTE effects.

354.05 – Probing Type Ia Supernova Host Galaxy Correlations: Insights from Model Testing

Brian Hayden[1], Gregory S. Aldering[1], Stephen Bailey[1], Dan Birchall[1], Michael Childress[1], Hannah Fakhouri[1], Alex G. Kim[1], Jakob Nordin[1], Peter E. Nugent[1], Saul Perlmutter[1], David Rubin[1], Karl Runge[1], Clare Saunders[1], Caroline Sofiatti[1], Nao Suzuki[1], Rollin Thomas[1], Benjamin Weaver[1], Emmanuel Pecontal[2], Clement Buton[3], Yannick Copin[3], Nicolas Chotard[3], Emmanuel Gangler[3], Rui Pereira[3], Gerard Smadja[3], Flora Cellier-Holzem[4], Arnaud Canto[4], Pierre Antilogus[4], Sebastien Bongard[4], Mathilde Fleury[4], Julien Guy[4], Reynald Pain[4], Juncheng Chen[5], Charling Tao[5], Ulrich Feindt[6], Peter Greskovic[6], Marek Kowalski[6], Simona Lombardo[6], Mickael Rigault[6], Charles Baltay[7], David L. Rabinowitz[7]
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The hottest current topic in type Ia supernova cosmology revolves around correlations between SN Ia peak brightness and properties of the SN host galaxy. We have compiled around 500 SNe with well-measured light curves and host galaxy photometry, from the Nearby Supernova Factory, the SDSS-II SN Survey, and the SNLS 3 year sample. We present various models for host correction based on host galaxy stellar mass and star-formation rate; the models are fit using a maximum likelihood method including intrinsic dispersion as a free parameter. Recent work has indicated that an element of the SFR is important in host galaxy corrections from SALT 2 light curve fits (Hayden et al. 2013, Rigault et al 2013), and we discuss our results in terms of these recent findings. Our large sample and maximum likelihood technique provide a unique perspective on SN Ia host galaxy analysis.

354.06 – On Numerical Considerations for Modeling Reactive Astrophysical Shocks

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Simulating detonations in astrophysical environments is often complicated by numerical approximations to shock structure. A common prescription to ensure correct detonation speeds (and associated quantities) is to prohibit burning inside the numerically broadened shock (Fryxell et al. 1989). We have performed a series of simulations to verify the efficacy of this approximation and to understand how resolution and dimensionality might affect its use. Our results show that, in one

dimension, prohibiting burning in the shock is important wherever the carbon burning length is not resolved, in keeping with the results of Fryxell et al. (1989). In two dimensions, we find that the prohibition of shock burning effectively inhibits the development of cellular structure for all but the most highly-resolved cases. We discuss the possible impacts this outcome may have on sub-grid models and detonation propagation in Type Ia supernovae.

354.07 – Advancing Nucleosynthesis in Core-Collapse Supernovae Models Using 2D CHIMERA Simulations

J. A. Harris[1], William R. Hix[2,1], Merek A. Chertkow[1], Stephen W. Bruenn[3], Eric J. Lentz[1,2], O. E. B. Messer[4,1], Anthony Mezzacappa[1,5], John M. Blondin[6], Pedro Marronetti[3,7], Konstantin Yakunin[1,2]
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The deaths of massive stars as core-collapse supernovae (CCSN) serve as a crucial link in understanding galactic chemical evolution since the birth of the universe via the Big Bang. We investigate CCSN in polar axisymmetric simulations using the multidimensional radiation hydrodynamics code CHIMERA. Computational costs have traditionally constrained the evolution of the nuclear composition in CCSN models to, at best, a 14-species α-network. However, the limited capacity of the α-network to accurately evolve detailed composition, the neutronization and the nuclear energy generation rate has fettered the ability of prior CCSN simulations to accurately reproduce the chemical abundances and energy distributions as known from observations. These deficits can be partially ameliorated by "post-processing" with a more realistic network. Lagrangian tracer particles placed throughout the star record the temporal evolution of the initial simulation and enable the extension of the nuclear network evolution by incorporating larger systems in post-processing nucleosynthesis calculations. We present post-processing results of the four *ab initio* axisymmetric CCSN 2D models of Bruenn et al. (2013) evolved with the smaller α-network, and initiated from stellar metallicity, non-rotating progenitors of mass 12, 15, 20, and 25 M™ from Woosley & Heger (2007). As a test of the limitations of post-processing, we provide preliminary results from an ongoing simulation of the 15 M™ model evolved with a realistic 150 species nuclear reaction network *in situ*. With more accurate energy generation rates and an improved determination of the thermodynamic trajectories of the tracer particles, we can better unravel the complicated multidimensional "mass-cut" in CCSN simulations and probe for less energetically significant nuclear processes like the ?p-process and the r-process, which require still larger networks.

354.08 – Multidimensional simulations of core-collapse supernovae with CHIMERA

Eric J. Lentz[1,2], Stephen W. Bruenn[3], Konstantin Yakunin[1,2], Eirik Endeve[2], John M. Blondin[4], J. A. Harris[1], William R. Hix[2,1], Pedro Marronetti[5,3], O. E. B. Messer[2], Anthony Mezzacappa[1,2]
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Core-collapse supernovae are driven by a multidimensional neutrino radiation hydrodynamic (RHD) engine, and full simulation requires at least axisymmetric (2D) and ultimately symmetry-free 3D RHD simulation. We present recent and ongoing work with our multidimensional RHD supernova code CHIMERA to understand the nature of the core-collapse explosion mechanism and its consequences. Recently completed simulations of 12-25 solar mass progenitors(Woosley & Heger 2007) in well resolved (0.7 degrees in latitude) 2D simulations exhibit robust explosions meeting the observationally expected explosion energy. We examine the role of hydrodynamic instabilities (standing accretion shock instability, neutrino driven convection, etc.) on the explosion dynamics and the development of the explosion energy. Ongoing 3D and 2D simulations examine the role that simulation resolution and the removal of the imposed axisymmetry have in the triggering and development of an explosion from stellar core collapse. Companion posters will explore the gravitational wave signals (Yakunin et al.) and nucleosynthesis (Harris et al.) of our simulations.

354.09 – 3D Core-Collapse Supernova Models: Gravitational and Neutrino Signatures

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Core-Collapse Supernovae (CCSN) are among the most promising sources for multi-messenger astronomy since they produce strong electromagnetic and neutrino signals, as well as powerful gravitational wave (GW) bursts. Our group has developed the CHIMERA code specifically to simulate CCSN in 1, 2, and 3 spatial dimensions, incorporating hydrodynamics, neutrino transport and thermonuclear kinetics. We present here first-principle 2D and 3D CCSN models covering, in the case of the 2D models, the first second after post-bounce. The 2D runs were based on 12, 15, 20 and 25M progenitors, with all developing full-blown explosions with energies up to 1 Bethe. The computationally expensive 3D run evolves a 15M progenitor and is currently undergoing. We provide an extensive analysis of the GW and neutrino signals obtained in those runs and study their detectability by Earth-based observatories.

354.10 – Testing an Asymmetric Explosion Model for Type Ia Supernovae with Optical Spectroscopy from SALT

Yssavo Camacho[1], Viraj Pandya[2], Curtis McCully[2], Brandon Patel[2], Saurabh Jha[2]
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Type Ia supernovae (SNe Ia) play a critical role in our cosmological understanding, but a detailed understanding of their progenitors and explosion mechanism remains elusive. The study of nearby SNe Ia, which can be observed to late epochs, provides an avenue to determine the physics of the explosion. Here we combine early-time and late-time optical spectroscopy from the Southern African Large Telescope (SALT) to test SN Ia explosion models. In particular, we measure nebular line shifts for two recent nearby SNe Ia, SN 2012fr and SN 2013aa, and connect these to maximum-light spectroscopic properties, to constrain asymmetry in the explosive thermonuclear burning that powers the SN Ia explosion. This work was supported by the National Science Foundation via the Research Experience for Undergraduates program, award PHY-1263280, at Rutgers, The State University of New Jersey.

354.11 – Supernova Shock Breakout Light Curves and Spectra from CASTRO Multigroup Radiation Simulations

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We present preliminary results from a study of supernova shock breakout with the new multigroup radiation transport version of the CASTRO simulation code. Shock breakout occurs when the outgoing shockwave of a supernova explosion reaches the surface of the progenitor star and produces a bright flash. The breakout flash's spectral temperature, duration, and luminosity carry information about the progenitor star that may otherwise be very difficult to recover. To aid in detection and understanding of this phenomenon, we present integrated light curves and spectra of breakouts from a range of progenitors and explosions, including very low energy supernovae and pair-instability supernovae.

354.12 – Lightcurves of Type Ia Supernovae from the La Silla-QUEST Survey and the Carnegie Supernova Project

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We present the first analysis of Type Ia supernovae found by the La Silla-QUEST (LSQ) survey and followed-up by the Carnegie Supernova Project (CSP) using the 1m SWOPE telescope. LSQ uses the 1m ESO Schmidt telescope on La Silla with a wide-band filter (4000-7000 Angstrom) to search for transient events with the aim of discovering and obtaining lightcurves for 500 low-redshift (z<0.1) supernovae over the 5-year lifetime of the project. The supernovae we present here are followed in a number of different filters, selected from BVugri, and will contribute towards the goal of a well-studied local sample for cosmology.

354.13 – The Metrology of Supernova Light Curves

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We model the Type Ia supernova light curve as the superposition of three luminosity pulses -- an initial pulse generated by the deposition of Ni-56 followed by the subsequent pulses generated by the radioactive decays Ni-56 ? Co-56 ? Fe-56. We assume that the two radioactive decays occur in a stable environment with density and temperature so high that the two decay rates are accelerated by the same factor. We use a three parameter Weibull probability density function to model the Ni-56 deposition so that the model can be written as a linear combination of the solutions to 2 coupled ordinary differential equations with 4 adjustable nonlinear parameters specifying the time of the onset of Ni-deposition, the shape and the scale of the deposition pulse, and the acceleration factor for the two decay rates. The two linear parameters specify the energies associated with the three processes and enables the estimation of the energy/nucleon emitted by the Ni-deposition. Fitting the model to the measured light curves for a sample of relatively nearby supernova gave fits that explained more than 99% of the total variance in every case. Such high fidelity to the measured data indicates that the fitted light curves may give more precise estimates of important parameters like the maximum luminosity and the time at which it occurs, the rise time to maximum luminosity, and the decline rate of the luminosity in the tail of the curve. Such improved precision should prove very beneficial in calibrating the extragalactic distance scale. For the small sample that has been analyzed thus far, the average of the estimates for the energy/nucleon in the Ni-deposition pulse is slightly greater than the binding energy of Ni--56 which indicates the fusion of 56 hydrogen nuclei into a Ni-56 nucleus.

354.14 – A Sample of Light Curves of Type II-n and other Unclassified Supernova

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It has long been speculated that there is a connection between supernova impostors and Type II-n supernovae. The modern Type II-n spectroscopic classification overlaps a great deal with Zwicky's "Type V" supernovae, which includes several impostors. In late 2012, SN 2009ip, a known impostor, may have exploded as a Type II-n supernova. The decline from that event exhibited unusual fluctuations in brightness that are not evident in other Type II-n light curves. We present the light curves of several more recent Type II-n supernova and compare them with other published samples.

354.15 – Bolometric Lightcurves and SEDs of Type Ia Supernovae

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We present an atlas of uvoir bolometric lightcurves and uvoir spectrophotometry of Type Ia supernovae covering space ultraviolet through NIR, 0.16 - 2.4 microns. Our data come from the SWIFT satellite, Carnegie Supernova Project and archival sources. The goals of this work are to create bolometric light curves and full spectrum SEDs of SNe Ia, of which only a handful currently exist, to better calculate S and K-corrections and to investigate the observational differences among the subclasses of SNe Ia. In addition, we will compare these SEDs to theoretical spectra of our collaborators. In analogy with the history of stellar atmospheres, we anticipate a mismatch between observation and theory, and the correction of theory to observation will allow us to construct semi-empirical opacities to be added into the radiative transfer of the theoretical models.

354.16 – NIR Spectra of Type Ia Supernovae: High-Cadence Observations

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Contributing teams: Carnegie Supernova Project II, CfA Supernova Group

New observing resources and coordinated scheduling make it possible to obtain sequences of NIR spectra from individual supernovae on a regular basis. In the past three years the Carnegie Supernova Project II and the CfA Supernova Group have obtained 350 NIR spectra of 78 supernovae. Here we describe eight series of NIR spectra from Type Ia supernovae for which there are ten or more observations with 4 or more of the spectra obtained before Mg II becomes undetectable at about six days post-maximum. NIR spectra are particularly useful for tracing the burning history of the outer layers in SN Ia and the presence of Mg II defines the limit of the carbon burning region. Recent analysis suggests that all significant absorption

features in spectra of SN Ia are blends of two or more lines. Data sets with higher spectral cadence are more successful at breaking line-identification degeneracies and consequently provide more accurate information about line profiles and velocity measurements. Three of the eight spectral series in this sample include more than 20 observations and in two cases, there are 12 spectra between -12d and +6d with respect to B-max. The eight SN Ia vary from -18.0 to -19.5 in absolute magnitude and we explore the differences between the supernovae in the timing and strength of spectral features. We make qualitative comparisons of these results to theoretical models for the chemical distribution of materials in SN Ia.

354.17 – Principal Component Analysis of Type Ia Supernova Spectrophotometric Time Series

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The spectrophotometric time series of over one hundred Type Ia supernovae from the Nearby Supernova Factory (Aldering, et al. 2002) provide unique opportunities for improving the standardization of Type Ia supernova magnitudes. We present results found by performing a Principal Component Analysis (PCA) on the spectral time series. We use Expectation Maximization PCA (Bailey, 2012), which can handle noisy or missing data, appropriate for the uneven phase coverage of the time series. We analyze the relationship between the number of principal components used to model supernovae and the amount of dispersion found in supernovae's corrected magnitudes. Additionally, we interpret the information contained in the individual principal components, such as their correspondence with already known Type Ia supernova characteristics like stretch and color.

354.18 – TIME VARIATION OF A_V AND R_V FOR TYPE Ia SUPERNOVAE BEHIND INTERSTELLAR DUST

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TIME VARIATION OF A_V AND R_V FOR TYPE Ia SUPERNOVAE BEHIND NON-UNIFORM INTERSTELLAR DUST ABSTRACT We investigate the time variation of the visual extinction, A_V, and the total-to-selective extinction ratio, R_V, resulting from interstellar dust in front of an expanding photospheric disk of a type Ia supernova (SN Ia). We simulate interstellar dust clouds according to a power law power spectrum and produce extinction maps that either follow a pseudo-Gaussian distribution or a lognormal distribution. The R_V maps are produced through a correlation between A_V and R_V. With maps of A_V and R_V generated in each case (pseudo-Gaussian and lognormal), we then compute the effective A_V and R_V for a SN as its photospheric disk expands behind the dust screen. We find for a small percentage of SNe the A_V and R_V values can vary by a large factor from day to day in the first 40 days after explosion.

354.19 – Understanding U-band Spectroscopic Variations in Type Ia Supernovae

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The Nearby Supernova Factory obtains spectrophotometric time series of Type Ia supernovae (SNe Ia). Observations include the so far poorly explored U band region, where we find significant flux variations best explained by different explosion scenarios (rather than e.g. metallicity changes). We show this using SYNAPPS fits of well measured SNe as well as non-parametric clustering algorithms applied to a larger sample of SNe. Both imply significant differences between narrow and wide lightcurve "normal" SNe Ia. The same data also allow us to map High Velocity features in the Ca H&K region, and we discuss how these relate to measurements of SN Ia lightcurve colors. We summarize potential effects on supernova cosmology based on these findings.

354.20 – Supernova Spectroscopy with the Southern African Large Telescope

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Supernova (SN) spectroscopy is important not only for classification and redshifts, but it also allows us to probe explosion mechanisms and progenitors. Here we report on optical spectroscopy of recent SNe using the Southern African Large Telescope (SALT) with the Robert Stobie Spectrograph (RSS). We have developed an automated data reduction pipeline for our longslit SN observations, paying particular attention to combining multiple exposures with different wavelength settings spanning the optical range. Furthermore, we investigate and implement an automated method for removing telluric features in the spectra. Finally, we present results exploring spectrum synthesis to model our growing database of type Ia supernovae.

354.21 – The Supernova Spectropolarimetry Project: Evolution of Asymmetries in the Very Luminous Type Ib SN 2012au

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The Supernova Spectropolarimetry Project is a recently formed collaboration between observers and theorists that focuses on decoding the complex, time-dependent spectropolarimetric behavior of supernovae (SNe) of all types. Using the CCD Imaging/Spectropolarimeter (SPOL) at the 61" Kuiper, the 90" Bok, and the 6.5-m MMT telescopes, we obtain multi-epoch observations of each target, aiming to construct the most comprehensive survey to date of supernovae in polarized light. In this poster we present the results of 6 epochs of spectropolarimetric observations of the Type Ib SN 2012au spanning the first 315 days of its evolution. This supernova was a very energetic, luminous, and slow-evolving event that may represent an intermediate case between normal core-collapse SNe and the enigmatic superluminous SNe (SLSNe). Strong, time-variable line polarization signatures, particularly in the He I λ5876 line, support previous hypotheses of an asymmetric explosion and allow us to trace detailed structures within the supernova ejecta as they change over time. We compare the spectropolarimetric evolution of SN 2012au with that of other objects in our data set and discuss its connections with other SNe Ib/c and SLSNe.

354.22 – The Supernova Spectropolarimetry Project: Results from Multi-Epoch Observations of the Type IIn SN 2010jl

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The Supernova Spectropolarimetry Project is a recently formed collaboration between observers and theorists that focuses on decoding the complex, time-dependent spectropolarimetric behavior of supernovae (SNe) of all types. Using the CCD Imaging/Spectropolarimeter (SPOL) at the 61" Kuiper, the 90" Bok, and the 6.5-m MMT telescopes, we obtain multi-epoch

observations of each target, aiming to construct the most comprehensive survey to date of supernovae in polarized light. We present results from the multi-epoch spectropolarimetric observations of the SN 2010jl. This type IIn supernova in UGC 5189A remained bright for an unusually long time allowing us to obtain 11 epochs of data over the course of 15 months. We find significant polarization in the continuum and variations in polarization across the Balmer and HeI lines. The measured polarized continuum decreased steadily over the 15 months of observations. This evolution allowed us to make a solid estimate of the interstellar polarization component thereby revealing the intrinsic supernova polarization. The polarization provides us with detailed information about the aspherical morphology of the explosion and the properties of the progenitor's pre-explosion mass loss.

354.23 – The Supernova Spectropolarimetry Project: Results from Multi-Epoch Observations of the Type IIb SN 2011dh

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The Supernova Spectropolarimetry Project is a recently formed collaboration between observers and theorists that focuses on decoding the complex, time-dependent spectropolarimetric behavior of supernovae (SNe) of all types. Using the CCD Imaging/Spectropolarimeter (SPOL) at the 61" Kuiper, the 90" Bok, and the 6.5-m MMT telescopes, we obtain multi-epoch observations of each target, aiming to construct the most comprehensive survey to date of supernovae in polarized light. Preliminary results from the SNSPOL project provide support for the increasingly popular hypothesis that many supernovae are aspherical explosion events. Thus far, we have observed 27 different SNe, many over multiple epochs, over the course of the last three years. While the history and evolution of these events is often studied with photometric and spectroscopic information, most supernovae are not studied with the combined advantage that spectropolarimetric data provides. The use of polarimetry allows us to probe the extent of the asphericity of the explosions while the use of spectroscopy allows us to characterize this asphericity across a variety of chemical species individually and as a function of velocity. Modern 3-D model simulations favor an explosion mechanism that is often inherently asymmetric in nature. Here, we showcase some of our initial results for the nearby type-IIb SN 2011dh that demonstrate the unique information that spectropolarimetric observations provide.

354.24 – Permitted spectral line features at late times in SN 2011fe?

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We present observations of optical spectra of the nearby type Ia supernova SN 2011fe at +100, +205, and +375 days post-maximum light. We also present spectral models which suggest that as late as day +100 and possibly later, spectra of this object exhibit effects of permitted line scattering. In particular, permitted lines of Fe II may be responsible for features frequently identified as emission lines of [Fe II] and [Fe III]. Strong permitted lines of Ca II are also likely present at these epochs, and possibly Na I as well. This suggests that the transition to forbidden line emission throughout the optical spectrum may take longer than previously expected.

354.25 – BVRI Photometry of SN 2013ej in M74

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The first announcements of the discovery of SN 2013ej in M74 appeared on July 26, 2013. I began measuring the brightness of the SN in Johnson-Cousins BVRI within 24 hours using a 30--cm telescope at the RIT Observatory. I will present light curves and color curves, and compare SN 2013ej to other type IIP events.

354.26 – Comprehensive Optical Observations of the Nearby Type Ia SN 2012fr

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The detailed study of nearby type Ia supernovae is critical for understanding their diversity, progenitor systems and explosion mechanisms. The type Ia supernova SN 2012fr exploded in late October 2012 in the galaxy NGC 1365, located only 18 Mpc away. SN 2012fr was caught just days after explosion, and so presents an excellent opportunity to study in detail the properties of a type Ia, and to put it into context with other nearby events. Here we present data from the LCOGT network over ~1 year, including 17 spectra from the FLOYDS robotic spectrograph. We measure light curve parameters for the supernova, and present a detailed spectroscopic analysis of this unique event.

354.27 – Examining the Late Time Evolution of the Luminous Type IIn Supernova 2010jl

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We present a sequence of 12 optical spectra of Supernova (SN) 2010jl obtained between a few and ~ 900 days following its discovery, as well as an epoch of late-time BVRI photometry. At a distance of ~ 50 Mpc, SN 2010jl is one of the nearest and brightest SNe in recent years, making it an excellent candidate for detailed study. The spectra are dominated by Balmer emission features, particularly Hα, which increase in strength significantly with time, suggesting interaction of the SN ejecta with dense, hydrogen-rich circumstellar material. Helium emission in the spectra show similar evolution. The development of the Ca II IR triplet and Fe II absorption at ~ 144 days indicate that the expanding outer shells of the SN ejecta have become optically thin, allowing us to see deeper into the core. At late times, the spectra begin to show a bluer continuum, but this may be due to contaminating light from the host galaxy. Combining these data with spectroscopic and photometric data already published in the literature, we estimate the optical spectral energy distribution of SN 2010jl as a function of time and construct a bolometric optical light curve. From this light curve we calculate the total energy radiated in optical light by SN 2010jl for approximately the first 800 days to be ~ 3.4×10^{50} erg.

354.28 – SN 2011ja: A Case of Circumsteller Interaction and Early Dust Formation

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We have found evidence for early dust formation and circumstellar interaction in the normal Type II supernova SN 2011ja using Gemini/GMOS, Spitzer/IRAC, and NTT/SOFI optical and infrared imaging and spectroscopy. Between March and April 2012, roughly 100-125 days past explosion, double-peaked, flat topped hydrogen emission lines appeared, in which the red-wing was noticeably attenuated. At the same time, mid- and near- IR fluxes indicate the existence of warm dust, likely due to a combination of newly-formed and pre-existing dust, heated by the initial flash into an IR echo. Further, detection of s-process elements like Sc, Ca, and Ba combined with massive amounts of pre-supernova mass loss could reveal the progenitor of SN 2011ja to be BSG. SN 2011ja is another example of a normal Type IIP SN which has quickly transitioned to a Type IIn-like object, due to the mass-loss history of the progenitor.

354.29 – SN 2012im/2013ek: A Supernova Double Take in NGC 6984

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Two H-poor supernovae - SN 2012im and 2013ek - both originating from massive stripped-envelope progenitor stars have been found at virtually the same location (< 0.4 arcsec). Chance alignment of two completely independent supernovae of the same Type Ib/c class exploding within one year of each other from the same stellar cluster is statistically improbable. Thus, the two explosions may be physically related, and this has important ramifications in areas of high-mass binary star evolution and explosion mechanisms of core-collapse supernovae. Here we present optical photometry and spectra of SN 2013ek beginning shortly after outburst, as well as Hubble Space Telescope images that pin down the supernova's precise location and probe the stellar environment of the progenitor system.

354.30 – The remarkably similar explosions of SN2009ip and SN2010mc, and the late fading of Type IIn supernovae

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The recent supernova (SN) known as SN2009ip had dramatic pre-SN eruptions characteristic of LBVs, followed by a final explosion in 2012. Its pre-SN observations make SN2009ip by far the best observed SN progenitor in history, but the unprecedented information about the pre-SN activity has fueled some debate about the nature of the 2012 explosion --- whether it was a true SN or some type of very extreme non-terminal event. We argue that only a core-collapse SN provides a self-consistent explanation. The light curves for SN2010mc and SN2009ip are nearly identical, including the brief precursor event. However, from the time of maximum light onward, their evolution appears fully consistent with other examples of Type IIn supernovae. New late-time data for these two SNe are also consistent with the late-time decay previously observed in many Type IIn supernovae, none of which have a clear surviving progenitor or shown any resurgence of variability. We also present energetic arguments that favor a 1 Bethe explosion. With the explosion of such a very massive LBV-like star, SN2009ip provides strong evidence that something is wrong with standard stellar evolution models for massive stars.

354.31 – High velocity lines due to interaction between Type Ia supernova ejecta and a circumstellar shell: 1-D simulations

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Observations of Type Ia supernovae (SN Ia) have shown the presence of Ca, Si, and Fe features with velocities of 8,000-14,000 km/s higher than that associated with the photosphere of the supernova ejecta. Some studies have suggested the high velocity lines could be explained by interaction of the ejecta with a circumstellar medium (CSM). Using FLASH, we perform 1-D hydrodynamic simulation of interaction between the ejecta and a 2×10^{-2} M_\odot circumstellar shell of solar abundance. We use the Sobolev approximation to estimate the line optical depths as a function of time and position. The results of our simulation show two line generating regions: within the ejecta, and within the fast moving shell. The velocity separation between the line generating regions are consistent with the values observed in actual SN Ia, lending credence to the CSM shell model.

354.32 – How Stellar Mixing Can Explain the Overabundance of Type Ic Supernovae in Long-Duration Gamma-Ray Bursts

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Supernovae associated with long-duration gamma-ray bursts have provided evidence for the progenitors of these outbursts being massive stars. All the observed supernovae associated with long-duration gamma-ray bursts have been Type Ic supernovae, requiring an explanation of how all helium in the progenitor is lost. Previous studies have suggested solutions involving either finely tuned mass loss or mechanisms for hiding the helium from spectral analysis. We present results from stellar models with new convection algorithms, demonstrating that enhanced convection in massive stars may lead to depletion of stellar helium layers. Supernovae resulting from these helium-depleted stars would not show any observable helium because it is not present in the progenitor. This study is part of the LANL Supernova Light Curve Project, which is using radiation-hydrodynamic simulations and our Spectrum code to conduct parameter studies of the light curves and spectra of supernovae.

354.33 – STELLAR AUTOPSIES: THE ANALYSIS OF TWO GRB-SNE IN THE NEBULAR PHASE

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Spectroscopy and photometry of core-collapse supernovae (SNe) during the nebular phase (T>=40 days) can be used to constrain explosion characteristics, including asymmetry. Here we model the nebular phase light curves of two hydrogen-stripped SNe, SN 2003dh and SN 2006aj, associated with gamma-ray bursts 030329 and 060218, respectively. We estimate the kinetic energy, nickel mass and ejected mass of the explosions. Using Hubble Legacy data in the F814W [I-band], F625W [R-band], F606W [V-band] and F435W [B-band] filters taken between 50 and 450 days after the gamma ray bursts, we reconstruct the bolometric light curve and apply a spherically symmetric, radiative decay model. For SN 2003dh, we find a nickel mass of ~0.35 M_solar, and for SN 2006aj we find a nickel mass of ~0.18 M_solar. Both are in good agreement with estimates from early photometric data suggesting minimal asymmetry within the SN explosion. We compare our results with other supernovae associated with gamma ray bursts. This work is supported in part by the NSF REU and DOD ASSURE

354.34 – Galactic SNRs in the WISE all sky survey

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We have searched the WISE All Sky Survey data released in March of 2012 in an effort to locate mid-IR emission from supernova remnants. We searched the survey data for infrared counterparts to sources in the Green (2009) Galactic SNR Catalog. We cross-referenced our detections with archival data from other wavelengths including X-rays (Chandra, XMM and ROSAT), radio (MOST) and optical (SuperCOSMOS, VTSS and SHASSA). In the WISE survey data, we have found SNRs with a variety of morphologies at 22 microns, consistent with emission from shocked dust. The detections include four remnants with no prior reported infrared detections: G156.2+5.7, G272.2-3.2, G349.7+0.2 and G11.2-1.1. We have estimated or placed upper limits on fluxes and shocked dust masses for these SNRs.

354.35 – Supernova science with LCOGT

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Las Cumbres Observatory Global Telescope Network (LCOGT.net) is a collection of nine robotic one meter telescopes with imagers spaced around the world in longitude, operated as a single network. There are also two robotic FLOYDS spectrographs on the two meter Faulkes telescopes in Siding Spring, Australia, and Haleakala, Hawaii. Here we describe recent supernova lightcurves and spectra with taken with LCOGT after being triggered from Pan-STARRS1, the La Silla-QUEST survey, the intermediate Palomar Transient Factory, and the IAU circulars. Since at least one telescope is always in the dark, and the facilities are robotic, LCOGT is uniquely suited to early-time supernova science.

354.36 – The Effects of Collective Neutrino Oscillations on Supernova Nucleosynthesis

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A core-collapse supernova originates from the implosion of the electron degenerate core inside a massive star. Runaway electron capture produces on the order of 10^{57} neutrinos containing about 10^{53} erg of energy in total. While the vast majority of neutrinos are eventually released, during the first few seconds these neutrinos drive both the dynamics, and likewise the nucleosynthesis, inside the supernova. Recently, our understanding of oscillations among the different flavors of neutrinos (electron, muon, and tau) has significantly improved, allowing us to ask if neutrino flavor change has a significant effect on nucleosynthesis in a core-collapse supernova. To investigate the effects of collective neutrino flavor oscillations, we use the hydrodynamic conditions from a spherically-symmetrical model of the implosion, bounce, and explosion of the 1.4 solar mass core that is inside an 8.8 solar mass star (Huedepohl et al. 2009). We select 20 mass tracers in the ejecta, varying in initial radii, and follow these trajectories for the first 9 seconds following bounce. We include these trajectories into a nuclear reaction network in order to calculate the detailed nucleosynthesis. We use three sets of neutrino reaction rates, all of which are calculated consistently with the conditions in the supernova model: (i) no collective flavor oscillations, (ii) collective oscillations for normal neutrino mass hierarchy, and (iii) collective oscillations for inverted neutrino mass hierarchy. We calculate the detailed nucleosynthesis for each trajectory for all three sets of neutrino rates. We find that the inclusion of collective oscillations (ii or iii) significantly increases the free neutron abundance; however, we obtain similar results regardless of which hierarchy is used. The increase in free neutrons also increases the subsequent rate of neutron capture, but has only a small effect on the predicted final abundances. This work was performed as part of North Carolina State University's Undergraduate Research in Computational Astrophysics (URCA) program, an REU program supported by the National Science Foundation through award AST-1032736.

354.37 – ALMA resolves SN 1987A's dust factory and particle accelerator.

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Contributing teams: SN1987A ALMA Cycle 0 Team

SN1987A in the Large Magellanic Cloud is the closest supernova to earth to be observed since 1604, making it a unique laboratory to study supernova physics in real time. Among SN87A's remarkable properties are a very large mass of new dust forming in the supernova ejecta. This dust was inferred from Herschel data, but its location not proven since Herschel could not resolve the 1.8" diameter remnant. Another mystery is whether the explosion left behind a neutron star - neither pulsar nor pulsar wind nebula has been detected so far. Excess emission from a PWN should be easiest to detect at millimeter wavelengths, if it can be spatially resolved from the synchrotron-emitting supernova shock. We present the first spatially resolved images of SN1987A at 450um, 870um, and 1.4mm, observed with the Atacama Large Millimeter/Submillimeter Array (ALMA). ALMA resolves emission from the newly formed dust, unambiguously locating it within the ejecta, interior to the reverse shock. The shocked ring is also well-resolved, and separated spatially from the ejecta. The ring shows no spectral break compared to centimeter wavelengths, and no free-free or PWN emission is required to explain the data. We discuss physical properties of the components of the remnant determined from these high resolution ALMA images.

354.38 – Recalibration of the Lightcurve of SN 2011fe

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We report the results of recalibration of observations of supernova 2011fe, with new instrumental files. observations were obtained with the TU 0.4m telescope from late August of 2011 through October of 2012. As reported by Storrs (2013) the supernova stays bright in the blue band more than in the green or red. We will report the results of a search for light echoes from this target as well. Reference: Storrs, A. (2013): "A Visible Lightcurve of Supernova 2011fe", abstract 251.11, 221st the American Astronomical Society

354.39 – Spectropolarimetry of SN 2011fe

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The Supernova Spectropolarimetry Project is a recently formed collaboration between observers and theorists that focuses on decoding the complex, time-dependent spectropolarimetric behavior of supernovae (SNe) of all types. Using the CCD Imaging/Spectropolarimeter (SPOL) at the 61" Kuiper, the 90" Bok, and the 6.5-m MMT telescopes, we obtain multi-epoch observations of each target, aiming to construct the most comprehensive survey to date of supernovae in polarized light. We present spectropolarimetry of SN 2011fe obtained for 8 epochs from August 2011-April 2012. The near-peak spectra show the evolution of the SiIIλ6355$\AA\$ feature, as well as other polarized line features. The late nebular spectra show the line ratios and line profiles of the forbidden iron-peak elements. The spectral series permit estimation of the interstellar polarization. Collectively, these observations permit a study of the evolution of the emission from a NUV-blue type Ia supernova.

354.40 – Impact of Rotation to the Pair-Instability Supernovae

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Recent study of the Pop III star formation suggests that the first stars could be born with a rapid rotation. Rotation within stars can affect their evolution and their SN explosion. In this poster, we use numerical simulations to study the rotating pair-instability supernovae (PSNe). We perform a series of 2D calculations to study the impact of rotation at the explosion phase of PSNe. Results show that rotation leads to an aspherical explosion of PSNe. For pre-SN models with a 50% critical rotation rate of the oxygen core, the yield of Ni-56 can be reduced by about two orders of magnitude. Rotation can also generate some fluid instabilities.

354.41 – A study of colliding white dwarfs acting as a progenitor of Supernova 1a

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Supernova Ia may be the result of colliding white dwarfs. To explore this possibility, we study of how varying the parameters of two 0.6M white dwarf stars colliding affects the final nickel and silicon yield using the FLASH 4.0 hydrodynamics code. Impact parameters starting at 0 (head on) and ranging to 5e8 km were studied. Production of 56Ni and 28Si were recorded for each parameter and we found that only collision parameters of 0, 2 and supposedly 1e8 would produce 56Ni > 0.1M necessary to produce a Type 1a Supernova.

354.42 – Discovery of a Gravitationally Lensed Type Ia Supernova

Robert Quimby[1]
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Recently, Pan-STARRS detected an unusual optical transient named PS1-10afx. While it has been argued PS1-10afx is a new type of superluminous supernova, we find that it is, in fact, a normal Type Ia supernova: its spectra are well matched by normal Type Ia exemplars such as SN 1994D, and its photometry has the colors and light curve shape expected for a Type Ia supernova at z=1.39; however, it is some 3.7 magnitudes too bright. We show that this excess brightness is caused by the gravitational lensing of the supernova by a foreground object, and we present new observations revealing the nature of this lensing object.

354.43 – Using the UV Lever Arm To Probe Type IIn Supernovae Shells

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Type IIn supernovae (SNe) are intrinsically bright, with a substantial fraction of the bolometric luminosity (usually at early times) contained in the UV. As such, they are promising candidates as probes of star formation out to high redshifts; however, their UV properties are currently poorly understood. Only recently has the sample size of well observed UV Type IIn SNe become available. Using this new sample, and the fact that the UV brightness particularly provides an excellent lever arm for quantifying differences in absorption columns and metallicity, we are positioned to place limits on the key parameters of the ejected shell. We are working to create a grid of Type IIn SNe shell models by varying four shell parameters: mass, thickness, metallicity, and mass loss. These models will then be compared with the recent sample of Type IIn SNe, obtained with the Swift Ultra-Violet/Optical Telescope (UVOT), in order to constrain the appropriate shell parameters. Here we show the comparison to models that have varied the mass.

355 – Dwarf & Irregular Galaxies Poster Session

Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

355.01 – A Quest For Stellar Streams

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The Milky Way's dwarf satellite galaxies provide tests of theoretical predictions concerning the number and internal structure of low-mass dark matter halos. Here, we present results from high precision velocities attained with Hectochelle spectroscopy of 166 and 799 stellar targets around the Milky Way satellites Draco and Segue 2, respectively. We find ~60 likely members of Draco and ~13 likely members of Segue 2 and use these samples to estimate velocity dispersions and dynamical masses. Finally, we search for evidence of tidal features in order to explore a potential solution to the core/cusp and missing satellite problems. This work is supported in part by the National Science Foundation REU and Department of Defense ASSURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.

355.02 – Machine Learning Identification of Dwarf Galaxy Satellites around Milky Way Analogs

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The Milky Way galaxy (MW) hosts approximately two dozen known dwarf galaxy satellites, ranging from the bright Magellanic Clouds, to the fainter dwarf spheroidal galaxies, including Leo I and Fornax, to ultra-faint dwarfs. Galaxy formation simulations predict that, down to the luminosity of Fornax, roughly three times more satellites should exist than we observe. However, the MW is a small and possibly biased sample. No MW analog satellite populations have yet been studied to these luminosities, because identifying the satellites around a MW analog requires spectroscopic observations of all objects within the virial radius to distinguish the satellites from the significantly more numerous background galaxies. Here, we apply machine learning techniques, specifically the use of an artificial neural network (ANN), to the problem of identifying satellites around MW analogs based on photometric observables, which are more easily obtained than spectroscopy. The ANN is trained on a set of labeled satellites and background galaxies around ~100 MW-like hosts, then applied to a validation data set to evaluate its performance. This work is carried out in parallel with a long-term spectroscopic observing program of several MW analogs, which will increase the training set size and improve the ANN's performance.

355.03 – The M31 Asymptotic Giant Exploration Survey: Intermediate-Age Stellar Content in Andromeda VII

Karen Hamm[1], Rachael Beaton[1], Katherine Hamren[2], Martha L. Boyer[3], Puragra Guhathakurta[2], Steven R. Majewski[1]
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Contributing teams: M31AGES collaboration

In a Lambda-CDM cosmology, much of the stellar content in galaxy haloes is built up through the hierarchical merging of less massive satellite galaxies. While there exists abundant evidence for these accretions in the Milky Way and Andromeda (M31) stellar haloes, it is still unknown what fraction of the halo is accreted and what fraction was formed in-situ. One means of determining this fraction is by characterizing intermediate age (2-6 Gyr) stellar content in stellar haloes, which most likely were formed in satellite galaxies and then removed through the accretion process. The M31 Asymptotic Giant Exploration Survey (M31AGES) aims to address this question by identifying asymptotic giant branch stars (AGB) in the M31 stellar halo to produce the first age-profile for a MW-sized stellar halo. Here, we present first results from the survey for the satellite dwarf galaxy Andromeda VII, in which we have several dozen AGB candidates selected from optical + near-infrared photometry. We follow-up these candidates with low resolution spectroscopy from MMT+Hectospec to determine their spectral type and to estimate contamination fractions in our photometric selection criteria.

355.04 – Metallicity Distribution Functions and Chemical Evolution Models of 4 Local Group Dwarf Galaxies.

Teresa Ross[1], Jon A. Holtzman[1], Barbara J. Anthony-Twarog[2], Abhijit Saha[3]
1. New Mexico State University, Las Cruces, NM, United States. 2. University of Kansas, Lawrence, KS, United States. 3. NOAO, Tuscon, AZ, United States.

Metallicity, age, and mass are fundamental characteristics of a stellar population. Metallicity distribution functions (MDFs) along with chemical evolution models, contain information on the history of enrichment, inflow, and outflow within the galaxy. MDFs for Leo I, Leo II, IC 1613, and Phoenix dwarf galaxies were derived from photometry from the Wide Field Camera 3 (WFC3) instrument aboard the Hubble Space Telescope (HST). While the metallicity accuracy (~0.2 dex) in our study is lower than spectroscopic measurements we can reach fainter magnitudes and measure every star in the field, producing an order of magnitude more stellar metallicities than previous studies. We fit the MDFs of four Local Group dwarf galaxies to analytical chemical evolution models to quantify the affect of gas flows and star formation within the galaxies.

355.05 – The Formation History of the Ultra-Faint Dwarf Galaxies

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We present early results from a Hubble Space Telescope survey of the ultra-faint dwarf galaxies. These Milky Way satellites were discovered in the Sloan Digital Sky Survey, and appear to be an extension of the classical dwarf spheroidals to low luminosities, offering a new front in the efforts to understand the missing satellite problem. Because they are the least luminous, most dark matter dominated, and least chemically evolved galaxies known, the ultra-faint dwarfs are the best candidate fossils from the early universe. The primary goal of the survey is to measure the star-formation histories of these galaxies and discern any synchronization due to the reionization of the universe. We find that the six galaxies of our survey have very similar star-formation histories, and that each is dominated by stars older than 12 Gyr.

355.06 – The Haverford Variable Star Search: Ursa Major II and Bootes III

Andrea Gaughan[1], Eric Smith[1], Alexander Dillaire[1], Marian Bechtel[1], Beth Willman[1], Erin Boettcher[2]
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We present a search for RR Lyrae variable stars in two Milky Way satellites: Ursa Major II (UMa II) and Bootes III (Boo III). UMa II is one of the closest and most diffuse ultra-faint dwarf galaxies (M,V, = -4.0, d = 30 kpc). Boo III is an overdensity that may be a disrupted dwarf galaxy (M,V, ~ -5.8, d ~ 45 kpc). We conducted our search using B and V band time-series imaging obtained at the WIYN 0.9m/S2KB at Kitt Peak National Observatory, covering a 42 x 20 arcminute field on UMa II and a 38 x 20 arcminute field on Boo III. We identified several variable stars in the UMa II field and none in the Boo II field. We present these UMa II variable stars, one of which is a known RRab star, one of which is a foreground variable star, and three of which appear to be previously unknown RR Lyrae in UMa II. We use these RR Lyrae to derive a robust distance to UMa II. The work on this project has been supported by NSF AST-1151462.

355.07 – Discovery of Extreme AGB Stars in the Dwarf Galaxies of the Local Group: First Results from the DUST In Nearby Galaxies with Spitzer (DUSTINGS) program

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Asymptotic Giant Branch (AGB) stars may be the dominant stellar dust source in galaxies, potentially driving galactic chemical evolution. Specifically, the dustiest ``extreme'' AGB stars, which comprise <5% of the AGB population, provide more than 70% of the AGB-produced dust in the Magellanic Clouds (Riebel et al. 2012; Boyer et al. 2012). Despite their importance, these stars have only been studied in detail in the Magellanic Clouds, which cover a limited range in metallicity. Here, we present the first results of the DUST In Nearby Galaxies with Spitzer (DUSTINGS) post-cryogen Spitzer program. The DUSTINGS program was designed to identify and characterize these extreme AGB stars in a complete infrared census of resolvable Local Group (<2 Mpc) dwarf galaxies, which span a wide range of galactic environments. We find hundreds of extreme AGB star candidates and estimate their dust-injection rates.

355.08 – Spectral results for the blue plume stars in Canis Major Overdensity

Mirza Sharoz Rafiul Islam[1], Ronald J. Wilhelm[1]
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We will present distances and kinematics and look at the possible populations for the blue plume (BP) stars in the Canis Major Overdensity (CMO). We conducted a medium resolution spectral survey on the BP stars (N=303) in CMO (centered at l = 238o ; b = -8o) using the data from AAOmega Spectrograph. We used a modified version of the SNIP algorithm to normalize our fluxed absorption spectra. After determining the radial velocities from measurements of strong absorption features for the stars we use a Bayesian analysis of spectral feature strengths and photometric colors to determine Teff, Logg and [Fe/H]. Our procedure makes use of grid for model synthetic spectra computed using SPECTRUM with Atlas9 model atmospheres and Kurucz model colors. We determine the absolute magnitude using the stellar parameters and BaSTI isochrones and compute distances and ages for the BP stars. From stellar calibration data using our procedure our preliminary results suggest this technique can produce both reddening and distance determinations to within 10%. We will report on the spatial, kinematic, metallicity and age distribution for the BP stars at the center of the Canis Major Overdensity.

355.09 – Dynamical and Population Gradients Within the Sagittarius dSph Galaxy

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Contributing teams: APOGEE Team

The Sagittarius (Sgr) dwarf spheroidal (dSph) galaxy is presently merging with the Milky Way and is thus a prototype for substructures that participate in the hierarchical build-up of our galaxy. Using highly precise radial velocities from over 320 stars observed by the Apache Point Galactic Evolution Experiment (APOGEE) of Sloan Digital Sky Survey III, we have verified with strong significance the existence of a dynamical cold point in the center of the satellite (Majewski et al. 2013, ApJL, in press). Stellar parameters and abundances derived from the APOGEE pipeline have shown evidence for a metallicity gradient that suggests that this cold point may be related to differences in the distributions and dynamics of multiple stellar populations within the Sgr dSph. In this study we further explore the stellar populations and kinematics of the Sgr dSph by expanding our sample to include ~40 recently acquired APOGEE targets as well as over 300 additional members from R~15,000 spectroscopic observations obtained with the Hydra spectrograph on the Blanco 4m at Cerro Tololo Inter-American Observatory (see Frinchaboy et al. 2012, ApJ, 756, 74). This expanded data set provides us with 4 times greater radial coverage (out to ~6 kpc from the center) for a more comprehensive investigation of the dynamics and stellar populations of this relatively large satellite of the Milky Way Galaxy.

355.10 – A Photometric Classification of the SAGE LMC Point Source Catalog

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Contributing teams: SAGE Collaboration

The Spitzer SAGE Large Magellanic Cloud (LMC) photometric catalog lists over 7.2 million sources detected with the Spitzer space telescope. This catalog has been cross-correlated with the near-IR 2MASS and IRSF surveys, as well as with optical photometry from the MCPS database. This combined catalog is an invaluable tool for the study of LMC stellar populations, and to understand the life cycle of gas and dust in the LMC. To fully leverage the broad wavelength coverage of this database, we have developed a novel technique for the photometric classification of the SAGE LMC point source catalog, based on a weighted k-Nearest Neighbor method. This technique allows the classification of most LMC sources based on templates that have been identified spectroscopically, without a-priori assumptions about their spectral characteristics. We present here the details of our classification method, and the main results of our work.

355.11 – The GALEX Catalog of UV Sources in the Magellanic Clouds

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The Galaxy Evolution Explorer (GALEX) has performed unprecedented imaging surveys of the Magellanic Clouds (MC) and their surrounding areas including the Magellanic Bridge (MB) in near-UV (NUV, 1771-2831 Å) and far-UV (FUV, 1344-1786 Å) bands at 5? resolution. Substantially more area was covered in the NUV than FUV, particularly in the bright central regions, because of the GALEX FUV detector failure. The 5? depth of the NUV imaging varies between 20.8 and 22.7 (ABmag). Such imaging provides the first sensitive view of the entire content of hot stars in the Magellanic System, revealing the presence of young populations even in sites with extremely low star-formation rate surface density like the MB, owing to high sensitivity of the UV data to hot stars and the dark sky at these wavelengths. Crowding limits the quality of source detection and photometry from the standard mission pipeline processing. Therefore, we performed custom PSF-fitting photometry of the GALEX data in the MC survey region (<15° from the LMC, <10° from the SMC). After merging multiple detections of sources in overlapping images, the resulting catalog we have produced contains many million unique NUV point sources. This poster provides a first look at the GALEX MC survey and highlights some of the science investigations that the catalog and imaging dataset will make possible.

355.12 – Identifying Ranges of Stellar Ages and Metallicities for Blue Supergiants in the Starburst Galaxy IC 10

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Dwarf galaxies transition from active star formation to relative quiescence after entering a dense environment such as a galaxy cluster. However, the mechanism behind this change is not fully understood. The problem is complicated by its heavy dependence on the initial conditions of the galaxy in question. To investigate the conditions of a galaxy prior to transition, we chose one of the best and nearest examples of a dwarf with active star formation, the Local Group member IC 10. We have obtained DEIMOS spectra of blue supergiants in this galaxy and determined the range of metallicities and ages for these stars using the equivalent width of the calcium triplet feature and isochrone fitting to photometry. By looking at the distribution of these metallicities in space and time we are able to gain insight into IC 10's recent evolutionary history and to get a clearer picture of the physical state of a dwarf galaxy prior to transition.

355.13 – Westerbork Synthesis Radio Telescope HI Imaging of HI-selected Local Group Galaxy Candidates

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The paucity of low mass galaxies in the Universe is a long-standing problem. We recently presented a set of isolated ultra-compact high velocity clouds (UCHVCs) identified within the dataset of the Arecibo Legacy Fast ALFA (ALFALFA) HI line survey that are consistent with representing low mass gas-bearing dark matter halos within the Local Group (Adams et al. 2013). At distances of ~1 Mpc, the UCHVCs have HI masses of ~10^5 Msun and indicative dynamical masses of ~10^7 Msun. The HI diameters of the UCHVCs range from 4' to 20', or 1 to 6 kpc at a distance of 1 Mpc. We have selected the most compact and isolated UCHVCs with the highest average column densities as representing the best galaxy candidates. Seven of these systems have been observed with WSRT to enable higher spatial resolution (~40-60") studies of the HI distribution. The HI morphology revealed by the WSRT data offers clues to the environment of the UCHVCs, and velocity fields allow the underlying mass distribution to be constrained. The Cornell ALFALFA team is supported by NSF AST-1107390 and by the Brinson Foundation. JMC is supported by NSF grant AST-1211683.

355.14 – Very Large Array HI Imaging of 'H Alpha Dots'

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"Hα Dots" are compact sources of line emission that were discovered in a narrow-band imaging study of nearby, star-forming galaxies (Kellar et al. 2008, 2012). While located in close angular and velocity proximity to normal star-forming disk galaxies, they are not obviously associated with them. In Allan et al. (2010) we presented preliminary HI spectral line imaging of selected "Hα Dots" obtained with the Karl G. Jansky Very Large Array in the C configuration. Here present preliminary results from subsequent observations of these sources in the D configuration. The increased surface brightness sensitivity of the combined datasets allows us to determine if the Hα Dots are located within the target galaxies' gas envelopes, within tidal tails, or if they are isolated, extragalactic star-forming objects. We present HI moment maps and compare these to optical broad and narrow-band images of the same fields. JMC is supported by NSF grant AST-1211683.

355.15 – Very Large Array 14 GHz Continuum Imaging of Nearby, Star-Forming Galaxies

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We present new K_U band radio continuum imaging of three nearby starburst dwarf galaxies, NGC4449, NGC2366 and Holmberg II, obtained with the Karl G. Jansky Very Large Array. The wide bandwidth (2 GHz) allows a sensitive examination of the nature of radio continuum emission between 13 and 15 GHz. We compare these continuum images with tracers of very recent star formation (H alpha emission, probing the most recent few Myr) and with tracers of intermediate timescale star formation (GALEX near UV emission, probing timescales of ~200 Myr). When summed over the entire 2 GHz bandpass, the radio continuum emission morphology is qualitatively similar to that of the regions of highest H alpha surface brightness; however, in all three galaxies, there are regions of H alpha emission that are not detected at this sensitivity level in the 14 GHz continuum. Imaging individual 128 MHz spectral windows allows us to examine the variation of flux density with frequency on a spatially resolved basis. Combining with lower-frequency radio continuum imaging allows a separation of thermal and non-thermal emission components. A.N. and J.M.C. acknowledge support from Macalester College that made this work possible.

355.16 – Structural Parameters of the SHIELD Galaxies From Hubble Space Telescope Images

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The Survey of HI in Extremely Low-mass Dwarfs (SHIELD) is an ongoing study of twelve galaxies with HI masses between 10^6 and $4\mathrm{x}10^7$ M™, detected by the Arecibo Legacy Fast ALFA (ALFALFA) survey. Here we present new structural parameters of the SHIELD galaxies determined from Hubble Space Telescope (HST) images. The primary goal is an accurate determination of the optical surface brightness of each galaxy. We designed a custom IDL program, called CleanGalaxy, that allows accurate removal of foreground and background contaminants, and then automatically fits elliptical surface brightness contours as a function of galactocentric radius. The extracted surface brightness profiles are parameterized using standard scaling laws. We compare these structural parameters for all members of the SHIELD galaxies and present cumulative surface brightness measurements of each system. Support for this work was provided by NASA through grant GO-12658

355.17 – Magnetic Fields in the Irregular Galaxy NGC1156

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The magnetic fields of irregular galaxies may be important in their interstellar medium; however, not much is currently known about them. We have obtained continuum polarization observations from the VLA and Effelsberg telescopes of the irregular galaxy NGC 1156 to increase the sample of irregular galaxies with observed magnetic field structures. Significant polarization emission was observed at all three observed frequencies in the galaxy which shows the presence of the magnetic field and allows for study of its properties. From these data we obtain the synchrotron fraction, magnetic field strength, and magnetic field orientation. The rotation measure between the 6cm and 3cm observations provides information about the magnetic field strength and direction along the line of sight. Finally we compare the magnetic field strengths with the other forces in the galaxy including the hot, warm, and cold gas pressures to determine the dominant force in the galaxy and role of the magnetic field.

355.18 – Radial Color and Mass Profile Trends of Dwarf Irregular Galaxies

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Contributing teams: LITTLE THINGS

Radial stellar surface brightness (SB) profiles of spiral galaxies can be classified into three types: (I) single exponential, (II) truncated: the light falls off with one exponential out to a break radius and then falls off more steeply, and (III) anti-truncated: the light falls off with one exponential out to a break radius and then falls off less steeply. Stellar SB profile breaks are also found in dwarf disk galaxies, but with an additional sub-category of Type II profiles: (FI) flat-inside: the light is roughly constant or increasing and then falls off beyond a break. Additionally, Bakos, Trujillo, & Pohlen (2008) showed that for spirals, each profile type has a characteristic color trend with respect to the break location which can be combined with color mass-to-light ratio relationships to examine radial mass profiles as well. Here we show radial color and mass profile trends for the three main SB types from a large multi-wavelength photometric study of dwarf irregular galaxies (the 141 dwarf parent sample of the LITTLE THINGS galaxies). We explore the similarities and differences between spirals and dwarfs and also between different colors.

355.19 – Globular Cluster Systems of Dwarf Elliptical Galaxies in Virgo and Fornax

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We present results of the metallicities, velocity dispersions, mass-to-light ratios, and dark matter content of a sample of Virgo and Fornax Cluster dwarf elliptical galaxies from their globular cluster systems. Between 5 and 9 globular cluster candidates have been identified in each galaxy from HST imaging and Gemini GMOS optical spectroscopy. Lick line-index measurements indicate that the globular clusters are old and metal-poor with low [α/Fe]. The velocity dispersions of the globular cluster systems are between 25 and 40 km/sec. These are consistent with the predictions based on the total optical luminosity and the mass-to-light ratios from the optical colors of the galaxies. Therefore, the globular clusters are likely to be bound. These relatively massive, $\sim 10^9$ M_{sun}, dwarf elliptical galaxies do not seem to be dominated by dark matter within a projected radius of 5 kpc.

355.20 – Keck spectroscopy and NGVS photometry in the direction of the Virgo cluster: Globular cluster satellites of dwarf ellipticals, Milky Way halo substructure, and large-scale structure in the background

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Contributing teams: Next Generation Virgo Cluster Survey collaboration

The Virgo cluster, the nearest large galaxy cluster, is a rich repository of dwarf elliptical (dE) galaxies. The formation mechanism of dE galaxies remains the subject of much debate. Dwarf galaxies in general are believed to be building blocks in the hierarchical growth of galaxies as per the "cold dark matter" model of structure formation. Globular cluster (GC) satellites serve as important tracers of dark matter in the outer regions of dEs (beyond 1 half-light radius). This project presents new spectroscopic data from Keck's DEIMOS, which specifically targeted low-luminosity ($17 < M_V < 15$) dEs and GC satellites, in the Virgo cluster. These data are among the deepest spectroscopic data ever taken in this region. Secondary science targets – Milky Way foreground stars and galaxies in the background – are also discussed. All targets were chosen based on photometric data from the Next Generation Virgo Survey (NGVS) and the Advanced Camera for Surveys Virgo Cluster Survey (ACSVCS). Further, these two surveys were critical to the tomographic analysis of spectroscopic targets. From this analysis we were able to: identify 117 GCs associated with any one of the 21 dE targets in the Virgo cluster, identify Milky Way foreground stars as part of the Virgo Overdensity or Sagittarius streams, quantify the velocity structure of these ongoing cannibalism events, and identify two new superclusters of galaxies in the background using redshift distribution. This research was carried out under the auspices of UCSC's Science Internship Program. We thank the National Science Foundation for funding support. ET was supported by a Fulbright fellowship.

355.21 – Globular Clusters as Tracers of Dark Matter in Virgo Cluster Dwarf Elliptical Galaxies

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Contributing teams: NGVS collaboration

Dwarf elliptical (dE) galaxies outnumber any other galaxy class in galaxy clusters, but their formation is still debated. Their angular momentum and mass distribution contains valuable information about the physical processes they have experienced since their formation. Combining the Next Generation Virgo Cluster Survey (NGVS) and the ACS Virgo Cluster Survey (ACSVCS), we have carried out a Keck/DEIMOS survey to estimate the dark matter mass and its distribution in dEs. We target globular cluster (GC) candidates as tracers of the potential well of a total of 21 dEs in the Virgo Cluster in the luminosity range $–17 < M_V < –15$. The sample comprises 117 GCs that are satellites of the 21 dEs and span out to ~7 half-light radii (Re). For each galaxy, we first compare the velocity distribution of the GCs against an escape velocity function for a pure stellar mass model, finding a moderate dark matter halo extending to ~7 Re. We then calculate the total mass within 1 Re with a dispersion-based estimator and the total mass to 7 Re with a projected mass estimator. We average our estimates to create a dE representative of our sample, finding mass-to-light ratios in solar units of ~4.5 for the inner regions and ~8–20 for the entire galaxy. This indicates that dEs are not dark matter dominated, neither in their inner nor in their outer regions. Our results represent the first estimate of dark matter content beyond ~2 Re for low-luminosity dEs. These mass estimates are consistent with the prevalent tidal stripping theory of dE formation, which explains the lack of a massive, extended dark matter halo. This research was carried out under UCSC's Science Internship Program. We thank the National Science Foundation for funding support. ET was supported by a Fulbright fellowship.

355.22 – Probing the Nature and Origin of Ultra-compact Dwarfs in Coma

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Ultra-Compact Dwarfs (UCDs) are poorly understood objects with disputed origins; establishing the nature of these enigmatic objects has important implications for our understanding of star formation, star cluster formation, the missing satellite problem, and galaxy evolution. Currently favored scenarios include formation as giant star clusters, either as the brightest globular clusters or through mergers of super star clusters, themselves formed during major galaxy mergers, or as remnant nuclei from tidal stripping of nucleated dwarf ellipticals. As part of the HST/ACS Coma Cluster Treasury Survey, we are using two-passband imaging to study the UCD population in this cluster. With an accurately known PSF, it is possible to measure effective radii for objects down to ~10% of the PSF FWHM. For the ACS/WFC FWHM ~of 0.1 arcsec, we find we can measure sizes as small as ~7pc at the distance of Coma. Since this is about the minimum size for UCDs, UCDs can therefore be identified with good success using ACS imaging alone. Besides identifying a large candidate population of UCDs

based strictly on size and color information, we have additionally spectroscopically confirmed 36 UCD Coma cluster members using Keck/LRIS. We discuss the likely formation scenarios for Coma cluster UCDs based on the properties and distribution of this UCD population.

355.23 – ESO 243-49's Small Friends: Finding Satellite Galaxies

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We present two candidate satellite galaxies found around ESO 243-49, the host of an off-center intermediate-mass black hole. We began the search for satellite galaxies with nine Hubble Space Telescope images (from the UV to the near-IR), extracted sources using Source Extractor, and finally, fit the type and redshift of our sources using HyperZ. Of the roughly 725 objects detected, two are identified as candidate satellite galaxies. These identified candidate satellite galaxies may provide insight into the nature of intermediate-mass black holes and the environments in which they form. Smullen was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program (AST-1262829).

355.24 – A Spectral Analysis of a Rare "Dwarf Eat Dwarf" Cannibalism Event

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We have used Keck/DEIMOS to conduct the first detailed spectroscopic study of the recently discovered stellar stream in the Large Magellanic Cloud analog NGC 4449. Martinez-Delgado et al. (2012), using the tip of the red giant branch (TRGB), found that both objects, the stream and NGC 4449, are at the same distance, which suggests that this stream is the remnant of the first ongoing dwarf-dwarf cannibalism event known so far. Learning about the orbital properties of this event is a powerful tool to constrain the physical conditions involved in dwarf-dwarf merger events. The low surface-brightness of this structure makes impossible to obtain integrated light spectroscopic measurements, and its distance (3.8 Mpc) is too large as to observe stars individually. In the color-magnitude diagram of the stellar stream there is an excess of objects brighter than the TRGB which are potential star blends. We designed our DEIMOS mask to contain as many of these objects as possible and, while some of them turned out to be background galaxies, a handful happened to be star blends in the stream. Our velocity measurements along the stream prove that it is gravitationally bound to NGC 4449 and put strong constraints on the orbital properties of the infall. This research was carried out under the auspices of UCSC's Science Internship Program. We thank the National Science Foundation for funding support. ET was supported by a Fulbright fellowship.

355.25 – Star Formation in Dwarf-Dwarf Mergers: Fueling Hierarchical Assembly

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We present early results from the first systematic study a sample of isolated interacting dwarf pairs and the mechanisms governing their star formation. Low mass dwarf galaxies are ubiquitous in the local universe, yet the efficiency of gas removal and the enhancement of star formation in dwarfs via pre-processing (i.e. dwarf-dwarf interactions occurring before the accretion by a massive host) are currently unconstrained. Studies of Local Group dwarfs credit stochastic internal processes for their complicated star formation histories, but a few intriguing examples suggest interactions among dwarfs may produce enhanced star formation. We combine archival UV imaging from GALEX with deep optical broad- and narrow-band (Halpha) imaging taken with the pre- One Degree Imager (pODI) on the WIYN 3.5-m telescope and with the 2.3-m Bok telescope at Steward Observatory to confirm the presence of stellar bridges and tidal tails and to determine whether dwarf-dwarf interactions alone can trigger significant levels of star formation. We investigate star formation rates and global galaxy colors as a function of dwarf pair separation (i.e. the dwarf merger sequence) and dwarf-dwarf mass ratio. This project is a precursor to an ongoing effort to obtain high spatial resolution HI imaging to assess the importance of sequential triggering caused by dwarf-dwarf interactions and the subsequent affect on the more massive hosts that later accrete the low mass systems.

355.26 – The Clustering of Star Formation in Nearby Galaxies

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We present an analysis of the clustering and spatial distribution of star formation in the irregular dwarf galaxy NGC4214, located at a distance of about 3 Mpc. Using data from the Hubble Space Telescope's Wide Field Camera 3, we progressively blurred images from 1-128 pixels (corresponding to .6 - 76 pc) in powers of 2 pixels, in the UV,U,B, and I bands. Using the software Source Extractor(SExtractor), the sources within each of the images were determined along with measurements of their flux and area. Using these data, the size and luminosity distributions were determined. The size distribution resulted in a power law of approximately -1.5 over 2 orders of magnitude. The luminosity distribution resulted in a power law slope of ~-1.2. These results are in agreement with the results obtained by Elmegreen et al. 2006 for the approximately twice distant galaxy NGC628. For further analysis, we have been deriving the angular two point correlation function in each band using the locations of the sources identified in each of the progressively blurred images. Our preliminary results indicate stronger correlation in the UV bands than at longer wavelengths, suggestive of the more clustered nature of massive, young stars. Taking into account previous work, we find evidence that the clustering of star formation is independent of galaxy type despite different triggers for star formation may be at work.

358 – Galaxy Clusters Poster Session
Poster Session – Exhibit Hall ABC – 08 Jan 2014 09:00 am to 06:30 pm

358.01 – Dwarf Galaxy Alignment in Nearby Galaxy Clusters

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We investigate the alignment of dwarf galaxies selected from a sample of nearby (z<0.2) Abell galaxy clusters. Cluster galaxies are culled based on their location in the cluster color-magnitude diagram with respect to the host-cluster red-sequence. We explore the alignment of dwarf galaxies with the major axis of both the brightest cluster galaxy and the cluster as defined by the location of the red-sequence galaxies. In addition, we also look for an alignment between the major axis of cluster galaxies and a radius vector from the cluster center. We compare our results to predictions from N-body simulations of structure formation.

358.02 – Merger Hydrodynamics of the Luminous Cluster RXJ1347.5-1145

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We present deep (186 ks) Chandra X-ray observations of baryonic gas hydrodynamics in the merging galaxy cluster RXJ1347.5-1145, a cool-core cluster at a redshift of 0.451. We find that, although the mean gas distribution in the primary cluster is well fit by a spherical beta model, the X-ray surface brightness distribution shows cold fronts to the west, south, and east of the cluster center that form a clockwise spiral, characteristic of gas 'sloshing' induced by a merger in the plane of the sky. Spectral analysis reveals temperatures ~20 keV southeast of the primary cluster, suggesting shock heating from a merging subcluster. We identify 2 edges in X-ray surface brightness forming a 'Mach-cone', coincident with the maximum Sunyaev-Zel'dovich decrement from previous work. We model the density across this shock feature, and use the Rankine-Hugoniot conditions to determine the Mach number and velocity of the shock. The Mach cone and excess X-ray emission associated with the subcluster gas are displaced to the south of the subcluster's central cD galaxy, suggesting that the subcluster gas has been stripped. We measure the X-ray luminosity of the subcluster gas, and use scaling relations to place a lower bound on the subcluster's total mass. Funding for this research has been provided in part by the Smithsonian Institution and NASA CXC grant GO2-13148X.

358.03 – Redshift Survey of a Sample of Galaxy Clusters

Emily Finney[1,3], Mischa Schirmer[2]
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Galaxy clusters, among the most massive objects in the universe, provide an excellent context for exploring the evolution of large-scale structure. Historically, galaxy clusters have most been identified by luminosity; however, this introduces bias against galaxies with a high mass-to-light ratio. Mass selection allows galaxy clusters to be studied using the parameter of most interest to physical cosmologists. To this end, I have analyzed data from a sample of mass-selected potential galaxy clusters which were followed up spectroscopically using the ESO Multi-Mode Imager (EMMI) on the New Technology Telescope (NTT) at La Silla Observatory, Chile. Twelve masks, encompassing nine possible clusters and over 400 spectra, were analyzed, and six of these objects were confirmed as galaxy clusters. These findings highlight the value of using weak gravitational lensing to find galaxy clusters, and reveal objects of value to physical cosmology.

358.04 – A Joint Optical & X-ray Analysis of the Triple Merging Cluster MACS J1226.8+2153

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We present a multi-wavelength characterization of the massive merging triple galaxy cluster MACSJ1226.8+2153 at z = 0.436, combining Chandra X-ray observations, deep Subaru optical imaging, and spectroscopic redshifts of hundreds of individual galaxies. We find good agreement between the spatial distribution of X-ray emission and optical light from red sequence cluster member galaxies. Redshifts of galaxies within the three cluster components are confirmed to be at a common redshift, and we detect no significant bulk line-of-sight peculiar velocity offsets between the three components. The

velocity distributions of two of the individual cluster components exhibit strong bimodality, indicating that they are not completely relaxed and may have recently undergone mergers themselves. From the X-ray surface brightness and temperature profiles there is a clear shock propagating from the most massive cluster component with a Mach number M = 1.48 +/- 0.20. This shock feature could either be a remnant of a recent interaction internal to this component, or a bi-product of the early stages of merger interactions between the three cluster-scale components. We also present evidence for three large-scale filaments extending from this complex system, indicating that MACS J1226.8+2153 lies at the center of a node of the cosmic web. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

358.05 – Analysis Of The Velocity Data Of Cluster A562

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We present a recent study of the dynamics of the cluster of galaxies Abell 562 intended to determine if ram pressure is responsible for the jet bending in the Wide-Angle Tailed (WAT) radio source located in the central elliptical galaxy. Given the properties of the jet and of the intra-cluster medium (ICM), a relative velocity between the galaxy and the ICM greater than 800 km/s is needed for this mechanism to bend the WAT jet. We find that the peculiar velocity of the WAT galaxy is 170±140 km/s which is not enough to produce the bending. This is based on the analysis of the velocity of 146 galaxy cluster members obtained with the Gemini Multi-Object Spectrometer (GMOS) at Gemini North. However, our analysis of these velocity data and archival Chandra data suggests that an off-axis merger occurred in this system. This type of merger typically produces bulk flow motions with peak velocities greater than 1000 km/s which should be enough to explain the bending of the jets.

358.06 – Star Formation and Substructure in Galaxy Clusters

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We investigate the relationship between star formation (SF) and substructure in a sample of 107 nearby galaxy clusters using data from the Sloan Digital Sky Survey (SDSS). Several past studies of individual galaxy clusters have suggested that cluster mergers enhance cluster SF, while others find no such relationship. We find higher SF fractions in multi-component clusters than in single-component clusters at almost all local number densities and clustercentric distances. In these multi-component clusters, we find lower SF fractions in regions between components than in regions elsewhere, as expected for the observed densities in these regions. Furthermore, we find weak correlations between SF fraction and several statistical measures of substructure. We suggest that, on average, cluster mergers are weakly related to SF enhancement in all regions of clusters.

358.07 – Estimating Radio Source Contamination for Large SZ Cluster Surveys with Data from the Atacama Cosmology Telescope

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Contributing teams: Atacama Cosmology Telescope

The prevalence of radio sources in galaxy clusters raises a possible systematic concern in the study of the Sunyaev-Zel'dovich (SZ) effect in large galaxy cluster surveys. Unaccounted for flux from these radio galaxies may bias both the selection function and resulting observables of SZ selected surveys. Previous work in characterizing this contamination has typically focused on fluxes extrapolated from measurements at radio frequencies or consist of millimeter data for only small samples of clusters. In order to extend these studies in a manner more suitable for large, millimeter wavelength SZ surveys, we present a statistical analysis of radio sources in millimeter-wave data. The empirical model constructed from this study allows us to extend millimeter observations from the Atacama Cosmology Telescope (ACT) to the large sky areas covered by radio surveys. We leverage this to constrain the effects of radio contamination for large cluster samples spanning different regions of mass-redshift space.

358.08 – The Gas Dynamics of Elliptical Galaxies in Virgo: Motion and Infall Toward M87

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Galaxy clusters are the most massive gravitationally bound systems in the Universe. Most of the baryonic matter in these objects is in the form of hot gas, typically 100 million K, which can be studied through X-ray observations. By measuring the redshifts of individual galaxies within a cluster, one can combine X-ray observations of the cold fronts around those galaxies to yield a full three-dimensional constraint on the cluster dynamics. Virgo, as the nearest rich cluster, provides an excellent opportunity to measure the motions of X-ray bright galaxies and their interaction with the hot intracluster medium (ICM), as has been done for NGC4472 (Kraft et al. 2011), M86 (Randall et al. 2008) and NGC4552 (Machacek et al. 2006). In this paper we describe the interaction of the hot gas in the outer regions of NGC4649 (M60) with the Virgo ICM and determine its velocity and direction of motion. Using data collected from the Chandra X-ray Observatory, we compare the gas characteristics of NGC4649 with those of other Virgo ellipticals and search for features indicative of ram-pressure stripping (tails, wings). We also compare the observed motions and infall toward M87 of these galaxies with hydrodynamic N-body simulations to better understand the cluster formation process and the large scale interactions of the galaxy gas with the cluster gas. This work was supported by Chandra grant G01-13141X and the Smithsonian Astrophysical Observatory.

358.09 – Novel, Efficient Way to Study Origins of Globular Cluster Bimodality - Calibration on MC Cluster NGC 1850a & Application to GCs in the Sombrero Galaxy

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Extragalactic globular clusters (GCs) are important probes of galaxy evolution because they are often easily recognized, are bright enough for integrated light spectroscopy on large telescopes, and especially because each is taken to be a simple stellar population (SSP = all stars born at once in same place from same stuff). However, galaxies often show a clear mix of "red" and "blue" GCs that may imply a mix of primordial and merger-generated/restimulated systems of indefinite age-metallicity. To break this degeneracy of integrated light, we must confirm the predictions of theoretical models of SSPs by studying closer, resolved SSPs whose age can be determined from characteristic, robust features such as the main-sequence turnoff (MSTO). This presentation highlights my PhD research to probe the age/metallicity evolution of systems of extragalactic, unresolved GCs using the SALT Fabry-Perot (FP) spectrometer to map standard Lick Indices --- a set of absorption features defined for the integrated light of galaxies (Worthey et al. 1994); ancillary data obtained with the Goodman Spectrograph on SOAR telescope will be compared. Extragalactic GC systems are studied in batches in detail with Multi Slit Spectroscopy (Norris et al. 2008) and Integral Field Units (IFU) (Trancho et al. 2006). The limitation on crowded fields and small field of view of these two methods, respectively, are their notable drawbacks. An FP, however, provides high spatial resolution across a wide field, allowing spectra of thousands of objects to be obtained in a sequence of exposures. At future very large ground telescopes with FPs (e.g. GMT), this technique, once validated, could become a compelling alternative to multi-fiber spectroscopy and multi-slit spectroscopy.

358.10 – Effect of Halo Mass on HI Gas Content of Galaxies in Groups and Clusters

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We combine the Sloan Digital Sky Survey (SDSS) and the Arecibo Legacy Fast ALFA (ALFALFA) Survey to study the distribution of cold atomic gas fraction of galaxies that reside in groups and clusters in local Universe. A careful cross-matching between galaxies in SDSS, ALFALFA, and SDSS halo group catalog produces a sample of galaxies with decent statistics in the stellar mass range $10^{8.4}$ M™ ? M∗ ? $10^{10.6}$ M™ and the halo mass range $10^{12.5}$ h^{-1} M™ ? M_h ? $10^{15.0}$ h^{-1} M™ for a range of projected distance from the group center 0.04 ? r/r_{vir} ? 2.0. In order to limit our study to group and cluster interaction processes (not tidal stripping in pairs), we remove close pairs that may be undergoing tidal interactions from the sample. We construct a comparison sample from the isolated field galaxies and investigate the radial distribution of the gas-to-stellar mass ratio for galaxies in groups and clusters relative to the comparison samples with similar stellar mass and redshift. We find that the gas-to-stellar mass ratio decreases toward the centers of groups with halo mass greater than ? $10^{13.8}$ h^{-1} M™ but find no such trend for galaxies in small halo mass groups. This halo mass dependent effect suggests that there is a threshold for efficient gas stripping due to interaction between galaxies and intracluster medium (ICM). This trend together with the HI line profile properties of our sample galaxies in groups and clusters is consistent with the ram pressure stripping. In particular, the observed relationship between stripping and halo mass is predicted by the classical Gunn-Gott ram pressure stripping criterion modified by scaling relations for galaxies and dark matter halo, which indicates that there is a threshold halo mass for efficient ram pressure stripping for given galaxy stellar mass and ICM temperature. This study was funded by NSF grant AST-000167932.

358.11 – Hot gas and the evolution of spiral-rich groups

Jan M. Vrtilek[1], E. J. O'Sullivan[1], Simona Giacintucci[2], Laurence P. David[1], Somak Raychaudhury[3, 4], William R. Forman[1], Christine Jones[1]

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States. 2. University of Maryland, College Park, MD, United States. 3. Presidency University, Calcutta, India. 4. University of Birmingham, Birmingham, United Kingdom.

The group environment --- the locus of most galaxies in the present-day Universe --- is particularly suitable, owing to high galaxy densities and low velocity dispersions, for study of the merging of spirals to form ellipticals. In particular, little is known about how the resulting ellipticals acquire hot gas halos (whether from stellar mass loss or from accretion of group gas). We here discuss our examination, relying principally on Chandra and GMRT data, of two groups that are at once compact, spiral-dominated, sufficiently X-ray bright, nearby, and in early stages of merging. For HCG92 (Stephan's Quintet), GMRT 610 and 327 MHz observations show diffuse extended radio emission. X-ray and radio emissions from the group are dominated by a bright north-south ridge associated with the interloper galaxy NGC 7318b, with the low temperature of X-ray gas (0.6 keV) indicating an oblique shock resulting from the interaction. Much of the gas now in the hot phase may have been produced by shock heating of cool material during galaxy interactions, with additional energy and metals injected by star formation. Radio spectral index mapping allows us to trace the relative contributions from the shock and from star formation. Within the ridge spectral information can also be used to estimate the radiative age of the electron population, providing information on the shock age. For HCG16 the nature and even the existence of a hot intragroup medium has been debated. With a combination of a very recent deep (150 ks) Chandra image and radio data already available, we expect to resolve questions about the existence, extent, and nature of hot gas in HCG 16; map the heavy element distribution; determine the hot gas mass compared to the HI deficit; examine the prevalence of shock heating and ram pressure stripping; and study the brightest point sources.

358.12 – The Environment Within Galaxy Clusters as Measured by the Gravitational Potential

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Living at one extreme of the mass distribution in the Universe are the galaxy clusters. These gravitationally bound objects are considered laboratories within which we can study the evolution of baryonic matter over a wide-range of environments: from their dense cores, to their slightly over-dense outskirts near the virial radius, to the field population. A typical measure of environment around a galaxy cluster is a galaxy's distance to the center of the cluster. This distance is most likely correlated to the underlying and localized mass density (e.g., in an NFW form of density). This radius is equally correlated with the gravitational potential. While it is difficult to observe the projected mass density profiles of large samples of clusters to beyond the virial radius, the projected gravitational potentials are easily observable via the galaxy kinematics. In this work, we use simulations and data to constrain the star-formation properties of galaxies as a function of their local gravitational potential.

358.13 – Determining Photometric Redshifts for Galaxy Cluster Candidates Detected by the Planck Mission

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One of the outcomes from the Planck mission was the discovery of new galaxy cluster candidates using the Sunyaev-Zel'dovich effect. Working with collaborators at USM, my project involved confirming which detections were clusters and which were false positives, and then finding the redshifts of the newly discovered clusters using Pan-STARRS optical data photometrically calibrated using stellar locus regression techniques on SExtractor cataloged images. The redshifts were determined using the greatest likelihood from a red-sequencing technique. The results from this method were the finding of redshifts for seven new clusters. Future work will include creating a bootstrapping method from redshifts gained on known clusters to their correct values and applying this to the new clusters, as well as tweaking the red-sequencing code to produce more redshifts for the clusters.

358.14 – Constraining the Viscosity of the Intracluster Medium with Cold Fronts

John A. ZuHone[1], Maxim L. Markevitch[1], James M. Stone[2], Matthew Kunz[2]
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Cold fronts, which are sharp, smooth surface brightness discontinuities seen in X-ray observations of galaxy clusters, are potentially powerful probes of the microphysics of the intracluster medium. Cold fronts appear mostly smooth and undisrupted by fluid instabilities, which indicates a suppression mechanism. One possibility is viscosity. We have performed simulations of sloshing cold fronts in galaxy clusters with isotropic and anisotropic Spitzer viscosity, while varying the suppression factor. We show that while isotropic viscosity suppresses essentially completely the Kelvin-Helmholtz instability along cold front surfaces, anisotropic viscosity has a much weaker effect. We also show that the degree of turbulence in the

sloshing cluster core is similar in the inviscid and anisotropic cases, while it is strongly suppressed with isotropic viscosity.

358.15 – Quantifying the Nature of Intracluster Light in a Fornax-like Cluster

Kathryn Harris[1, 2], Victor P. Debattista[2, 3], Adam Clarke[2], Benjamin B. Thompson[2], Duncan Farrah[1], Sara M. Petty[1]
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Using N-body cosmological simulations, we investigate the contributions of the cD galaxy, halo stars and disk stars to the intra-cluster light of a Fornax-like cluster at low redshift. Initial analysis indicates evidence for a difference between the radial concentrations within the cluster of unbound disk and halo stars. The ratio of young to old (disk to halo) stars contributions to the ICL may thus change as a function of radius from the centre of the cluster. We briefly discuss some wider implications of this result.

358.16 – Investigation of Extended Emission Line Regions in Intermediate Redshift BCGs.

Kevin Cooke[1], Christopher P. O'Dea[1], Grant Tremblay[1]
1. Rochester Institute of Technology, Rochester, NY, United States.

A multiwavelength investigation of HST and Spitzer data of BCG emission features. SDSS Data used as a comparison to the original HST and Spitzer data.

358.17 – The most distant galaxy clusters in the SPT Spitzer Deep Field Survey

Alessandro Rettura[1], S. A. Stanford[2], Daniel Stern[1], Simona Mei[3], Mark Brodwin[4], Anthony H. Gonzalez[5], Daniel Gettings[5], Matthew Ashby[6], James G. Bartlett[1], Piero Rosati[7]
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We present a sample of more than 300 galaxy cluster candidates at z>1.3 selected within 94 deg2 from the Spitzer SPT Deep Field (SSDF) survey. To discover distant clusters at z>1.3, we have used a three-filter algorithm based upon Spitzer/IRAC color ([3.6]-[4.5]>-0.1,AB) combined with a non-detection in shallow optical data. Our sample is selected to be a complete stellar mass-limited sample at z>1.3 and therefore has a well defined survey volume. The uniqueness of SSDF resides not just in its area, one of the very largest with Spitzer, but also in its coverage by deep observations for the Sunyaev-Zel'dovich (SZ) effect with the South Pole Telescope (SPT). Deeper observations are also planned with the new SPT camera, SPTpol, that will reach, for the first time, SZ clusters up to z~2 (George et al., 2012). This field also has deep X-ray observations from the XMM XXL Survey (Pierre et al., 2012). Thanks to this rich data set, we will be able to determine accurate cluster masses for the vast majority of our SSDF clusters at 1.3<z<2, and enable systematic study of the high-redshift cluster population at an important epoch in their formation.

358.18 – Searching for the Most Distant Galaxy Clusters

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The early phases of galaxy evolution can be studied by observing distant galaxies. A key parameter affecting the evolution of galaxies is their local environment. Currently, it is not understood why galaxies within high-density environments, such as galaxy clusters, are so massive, yet inactive. Galaxies in clusters are amongst the most massive in the universe, so they must have been actively forming stars at an earlier time. However, recent studies have shown that out to z = 1, the most distant redshift where clusters are well-studied, cluster galaxies are still largely inactive, suggesting the period of active star formation in cluster galaxies occurred at an even higher redshift. To understand when the primary formation of clusters and cluster galaxies occurs, we used data from the CFHTLS-Deep survey to search for overdensities of Lyman-break galaxies at redshifts z ~ 3. We will present the preliminary results of our search, which yielded 31 candidate proto-clusters of galaxies within the four CFHTLS Deep fields. We will perform colour analysis and obtain spectroscopic redshifts for the galaxies within these candidate clusters to determine if they are truly cluster members. The candidate clusters found could be among the most distant structures in the early universe and would allow us to study the earliest progenitors of the massive, inactive

galaxies we see in clusters.

358.19 – Evolution of Star Formation and H I Gas Content in Galaxy Groups

Adam Birenbaum[1], Kelley M. Hess[2], Eric M. Wilcots[1]
1. University of Wisconsin, Madison, WI, United States. 2. University of Cape Town, Cape Town, Western Cape, South Africa.

We present an analysis of the neutral hydrogen gas (H I) content, star formation histories, and distribution of galaxies in groups as a function of their parent halo mass. The Arecibo Legacy Fast ALFA survey α.40 data release allows us to study the H I properties of 742 galaxy groups in the volume of sky common to the Sloan Digital Sky Survey and ALFALFA surveys. The ALFALFA galaxies have been identified with SDSS optical counterparts and we assigned H I detected objects that fall below the limiting optical magnitude-thereby not contributing substantially to the estimate of the group stellar mass, but significantly to the total group H I mass. We found the gas fraction and the star formation histories as a function of group halo mass to reveal strong evidence for evolution in the gas content and spatial distribution of the high gas fraction members. It is evident that the infall of gas rich objects is important to the continuing growth of large scale structure at the present epoch.

358.20 – On the Origin of Bias, Scatter, and Evolution in Sunyaev-Zeldovich Effect Scaling Relations

Liang Yu[1], Katherine L. Nelson[1], Daisuke Nagai[1], Erwin Lau[1]
1. Yale University, New Haven, CT, United States.

In this work, we investigate the impact of cluster mergers on the Sunyaev-Zel'dovich (SZ) effect scaling relation using high-resolution cosmological simulations of 85 galaxy clusters. By following the time evolution of the SZ signal of simulated clusters, we show that the thermal SZ signal increases systematically by ~20% after a major merger, as the kinetic energy of gas motions decays into thermal energy. We find that this evolving thermal energy content contributes to scatter in the SZ observable-mass relation. Once we account for the non-thermal pressure provided by random gas motions, the total SZ signal of relaxed clusters exhibits no systematic evolution and its scatter is roughly halved. We discuss implications of our work in cluster cosmology with ongoing and future SZ surveys and prospects for measuring gas flow in clusters with upcoming X-ray and SZ observations.

358.21 – MApping the Most Massive Overdensity Through Hydrogen (MAMMOTH)

Zheng Cai[1], Xiaohui Fan[1], Fuyan Bian[2], Ian D. McGreer[1], Brenda L. Frye[1], Yujin Yang[3], Ann I. Zabludoff[1], Zhenya Zheng[4]
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We have undertaken a survey of the most massive and overdense galaxy structures in the early universe at z=2-4, traced by regions of the highest optical depth from IGM Ly\alpha absorption over large scale of 10-30 Mpc. These structures represent the most biased regions in the universe at the peak of galaxy formation epoch, bridging the most luminous quasars observed at z\sim 6-7 and the most massive clusters in the local universe. Cosmological simulation and early observations show a strong correlation between the optical depth of 1-D intergalactic Ly\alpha absorption and the 3-D mass overdensities. Based on the simulation and MMT high S/N observations, we have developed a novel technique to identify high-redshift overdense region by searching for high optical depth regions in quasar spectra and requiring that they are not associated with discrete high column density absorbers such as sub-damped Lyα (sub-DLA) or DLA systems. By examining absorption spectra of \sim 140,000 sight lines provided by SDSS-III quasar survey, we have searched the IGM overdensities over a volume of 10 Gpc^3. This survey volume is more than two orders of magnitude larger than any existing Lyman Break Galaxy survey, enabling the discovery of the rarest and most massive systems. We have selected one unique field with three large Ly\alpha absorption and seven quasars within 20 h^-1 Mpc. Our preliminary and shallow KPNO-4m narrowband + broadband imaging have revealed a significant overdensity of Ly\alpha emitters at bright-end associating with this system. In future, we propose to carry out the LBT/LBC multi-color imaging to probe this field in much deeper using BX galaxies down to L^*, and further take the LBT/MODS observations to spectroscopically follow-up the \sim100 BX galaxies in this most overdense field and map the 3-D structure associated with the largest intergalactic HI overdensity.

358.22 – Thermal and Shock Histories of Gas in Galaxy Clusters

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1. Yale University, New Haven, CT, United States. 2. Caltech, Pasadena, CA, United States. 3. Carnegie Observatories, Pasadena, CA, United States.

Galaxy clusters are the most recently formed cosmological objects in the universe, making them ideal for studying the interplay between cosmology and baryonic physics in structure formation. Understanding their formation and growth requires not only an understanding of the baryonic physics, but also the detailed dynamics of how gas accretes from cosmic filaments onto a cluster throughout its lifetime. One of the outstanding questions concerning galaxy clusters currently is the baryon deficit in their interior as well as non-equilibrium phenomena (such as turbulence and gas clumping) in the virialization regions. Recent X-ray and microwave observations have revealed detailed thermodynamic structure of the cluster hot gas from the core to their virial radii, making comparisons of gas accretion in simulations to observations a strong cosmological probe. In this work, we focus on quantifying gas accretion in non-radiative cosmological simulations of galaxy clusters, where the only significant changes in entropy will be due to shock heating. In order to track each gas element, we implemented a tracer particle module in the Adaptive Refinement Tree cosmological simulation code. By following the thermal histories of each tracer particle, we measure the Mach number of every shock the particle experienced and identify periods of significant shock-heating. Combining this with measurements of how the temperature distribution of regions of the halo change over time, we then investigate whether gas had significantly different histories based on whether they accrete straight from the cosmic background or by first accreting onto a subhalo, the change in accretion due to the mass of the final main halo, and the disruptive effect mergers have on the smooth accretion process. We discuss implications of our results for understanding recent deep Chandra X-ray observations of Abell 133 which revealed several unexpected structural features connected to its gas accretion, including a sharp cutoff in diffuse gas and the presence of significant gas clumping at large scales.

301 – AGN Across the Spectrum: I
Oral Session – National Harbor 11 – 08 Jan 2014 10:00 am to 11:30 am

301.01D – Using <i>Fermi</i> Variability to Locate the Blazar GeV Emission Zone

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The location of the GeV-flaring zone in bright *Fermi* blazars is an important topic of debate: is the GeV emitting zone (GEZ) located inside the sub-pc broad line region (BLR) or farther out in the pc-scale molecular torus (MT)? We recently presented a diagnostic that can be used to locate the GeV emission size using the energy dependence of the flare decay time (T_f). If the GEZ is located in MT, the flare will have distinguishably different values of T_f in different Fermi energies; if the GEZ is located in the BLR T_f should remain constant over the Fermi energy range. Here we show results of our method, applied to the brightest observed flares of objects such as 3C 454.3, PKS 1222+216, and PKS 1510-089, as well as the implications of our work for the location of the GEZ.

301.02 – The Extragalactic Background Light and the Detection of the Cosmic Gamma-Ray Horizon

Justin Finke[1], Alberto Dominguez[2], Joel R. Primack[3], Francisco Prada[4], Francisco Kitaura[5], Brian D. Siana[2]
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Contributing teams: Fermi-LAT Collaboration

The first statistically significant detection of the cosmic gamma-ray horizon (CGRH) that is independent of any extragalactic background light (EBL) model is presented in this talk. The CGRH is a fundamental quantity in cosmology. It gives an estimate of the opacity of the Universe to very-high energy (VHE) gamma-ray photons due to photon-photon pair production with the EBL. The only estimations of the CGRH to date are predictions from EBL models and lower limits from gamma-ray observations of cosmological blazars and gamma-ray bursts. Here, we present synchrotron/synchrotron self-Compton models (SSC) of the spectral energy distribution of 15 blazars based on (almost) simultaneous observations from radio up to the highest energy gamma-rays taken with the Fermi satellite. These synchrotron/SSC models predict the unattenuated VHE fluxes, which are compared with the observations by imaging atmospheric Cherenkov telescopes. This comparison provides an estimation of the optical depth of the EBL, which allows a derivation of the CGRH through a Monte Carlo analysis that is EBL-model independent. We find that the observed CGRH is compatible with the current knowledge of the EBL. We conclude showing that the detection of the CGRH allows us to estimate the expansion rate of the Universe from gamma-ray attenuation.

301.03 – The Cosmic Evolution of Fermi BL Lacertae Objects

Dario Gasparrini[1, 2], Marco Ajello[3], Roger W. Romani[4], Michael S. Shaw[4]
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Fermi-LAT has provided the largest sample of gamma-ray selected blazars to date. We use a uniformly selected set of 211 BL Lacertae (BL Lac) objects detected by Fermi-LAT to determine the luminosity function of this class of blazars and its evolution with cosmic time. To make it possible, we have obtained redshift constraints for 206 out of the 211 BL Lacs making it the largest and most complete sample of BL Lacs available in the literature. We find that for most BL Lac classes, the evolution is positive with a space density peaking at modest redshift (z ~ 1.2). The low-luminosity, high-synchrotron peaked (HSP) BL Lacs show an exception, with strong negative evolution and number density increasing for redshift ~ 0.5. Since this rise corresponds to a drop-off in the density of flat-spectrum radio quasars (FSRQs), a possible interpretation is that these HSPs represent an accretion-starved end-state of an earlier merger-driven gas-rich phase strengthening the genetic link between the 2 blazar subclasses. Finally we discuss, for BL Lacs, the known correlation between luminosity and photon spectral index which has implications for the so called `blazar sequence'.

301.04 – Fermi rules out the IC/CMB model for the Large-Scale Jet X-ray emission of 3C 273

Markos Georganopoulos[1], Eileen T. Meyer[2]

1. UMBC, Baltimore, MD, United States. 2. STScI, Baltimore, MD, United States.

The process responsible for the Chandra-detected X-ray emission from the large-scale jets of powerful quasars is not clear yet. The two main models are inverse Compton scattering off the cosmic microwave background (IC/CMB) photons and synchrotron emission from a population of electrons separate from those producing the radio-IR emission. These two models imply radically different conditions in the large scale jet in terms of jet speed and maximum energy of the particle acceleration mechanism, with important implications for the impact of the jet on the larger-scale environment. Georganopoulos et al. (2006) proposed a diagnostic based on a fundamental difference between these two models: the production of synchrotron X-rays requires multi-TeV electrons, while the EC/CMB model requires a cutoff in the electron energy distribution below TeV energies. This has significant implications for the gamma-ray emission predicted by these two models. Here we present new Fermi observations that put an upper limit on the gamma-ray flux from the large-scale jet of 3C 273 that clearly violates the flux expected from the IC/CMB X-ray interpretation found by extrapolation of the UV to X-ray spectrum of knot A, thus ruling out the IC/CMB interpretation entirely for this source. Further, the Fermi upper limit constraints the Doppler beaming factor delta <5.

301.05 – Using Swift to Obtain X-ray Monitoring of Fermi Blazars and X-ray Counterparts to Fermi Unassociated Sources

Abraham Falcone[1], Michael Stroh[1], Matthew Pryal[1]
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Two Swift programs are providing valuable, easily accessible, and automatically processed X-ray data to the community in near real-time, while also providing UV and optical data. The first program is a long-term monitoring program on Fermi blazars, as well as many other variable high energy sources, enabling multiwavelength campaigns, in-depth studies of flaring, and studies of long-term behavior. In the second program, we are using Swift to search for X-ray and UV/optical counterparts of unassociated Fermi gamma-ray sources, which are likely to be dominated by new gamma-ray blazars and may also harbor pulsars, as well as new exciting source classes. This Swift program includes pointed observations, with typical durations of ~4 ks, of Fermi catalog sources with no currently known source association at other wavelengths. For each of the Fermi-LAT localization ellipses, Swift-XRT obtains accurate source positions (~5 arcsec) of any detected X-ray sources, enabling new blazar identification observations and pulsation searches at both radio and gamma-ray wavelengths. Together with follow-up at other wavelengths, this study aims to reveal the nature of these unassociated and unidentified gamma-ray sources. Some results from these programs will be presented, along with information about the public availability of the processed data in near real-time.

301.06 – Tracing the evolution of AGN host galaxies over the last 9 Gyrs

Andy D. Goulding[1], William R. Forman[1], Ryan C. Hickox[2], Christine Jones[1], Stephen S. Murray[3], Alessandro Paggi[1], Matthew Ashby[1], Alison L. Coil[4], Michael Cooper[5], Jiasheng Huang[1], Ralph P. Kraft[1], Jeffrey Newman[6], Steven P. Willner[1]
1. Harvard Smithsonian, CfA, Cambridge, MA, United States. 2. Dartmouth College, Hanover, NH, United States. 3. Johns Hopkins University, Baltimore, MD, United States. 4. University of California, San Diego, CA, United States. 5. University of California, Irvine, CA, United States. 6. University of Pittsburgh, Pittsburgh, PA, United States.

I will present new results from a combined galaxy population analysis of the host galaxies of active galactic nuclei (AGN) identified at 0<z<1.4 within the SDSS, Boötes and DEEP2 surveys. We have used a sophisticated sample selection technique to combine the galaxy populations in these three surveys and identified AGN at X-ray, infrared and radio wavelengths. Through comparison of the AGN hosts, we find that radiatively efficient (X-ray/IR) AGN are predominantly hosted in modest star-forming galaxies, with little dependence on AGN or galaxy luminosity, while those AGN exhibiting radio-emitting jets, due to mechanically-dominated accretion, are almost exclusively observed in massive passive galaxies. Crucially, we present strong evidence that the observed host-galaxy trends are independent of redshift. In particular, these different accretion-mode AGN have remained as separate galaxy populations throughout the last 9 Gyrs. Furthermore, those galaxies hosting AGN have evolved along the same path as galaxies that are not hosting AGN, with little evidence for distinctly separate evolution. This research acknowledges support from the Smithsonian Institution.

301.07 – Detection of cm to sub-mm band radio and gamma-ray correlated variability in Fermi bright blazars

Lars Fuhrmann[1], Stefan Larsson[2], James Chiang[3], Emmanouil Angelakis[1], Anton Zensus[1]
1. Max-Planck-Institut fuer Radioastronomie, Bonn, NRW, Germany. 2. Oskar Klein Centre, Department of Astronomy, Stockholm University, Stockholm, Sweden. 3. Department of Physics and SLAC National Accelerator Laboratory, Stanford University, Stanford, CA, United States.

The exact location of the gamma-ray emitting region in blazars is still controversial. In order to attack this problem we performed a detailed statistical cross-correlation analysis between radio (cm/mm/sub-mm wavelengths, F-GAMMA program) and gamma-ray 3.5 year light curves of 54 Fermi bright blazars. In this talk, the main results of this analysis are highlighted including the first significant detection of multi-band radio/gamma-ray correlations using a stacking analysis. The radio bands are usually lagging the gamma rays with average time delays (source frame) ranging between 76+/-23 and 7+/-9 days, systematically decreasing from cm to mm/sub-mm bands following a power-law frequency dependence. The latter is in good agreement with synchrotron self-absorption dominated opacity effects, whereas a (positive) time lag of 12+/-8 days at 3 mm strongly suggests that the bulk gamma-ray production region is usually located within or even upstream of the innermost mm core region of these sources. Based on our findings we finally demonstrate that the gamma-ray emitting region of quasar 3C 454.3 is located at a distance of > 0.8-1.6 pc from the central supermassive black hole, i.e. at the outer edge of the Broad Line Region or beyond.

301.08 – AGNs in Dwarf Galaxies? Evidence from WISE and XMM-Newton

Nathan Secrest[1], Shobita Satyapal[1], Mario Gliozzi[1], Teddy Cheung[2]
1. George Mason University, Fairfax, VA, United States. 2. Naval Research Labratory, Washington, DC, United States.

Whereas supermassive black holes (SMBHs) are ubiquitous in most major galaxies, evidence for the presence of SMBHs in dwarf galaxies is extremely rare. We present our XMM-Newton analysis of SDSS J132932+323417, one dwarf galaxy out of a large population of optically-quiescent dwarf galaxies revealed by WISE to have extreme mid-infrared colors indicative of the presence of an accreting supermassive black hole. Our observations reveal the presence of a hard X-ray point source with spectral properties characteristic of AGNs. This finding represents a major step in the understanding of SMBHs in dwarf galaxies, and potentially opens a new avenue into the study of AGNs in this rare class of objects.

302 – Data Handling & Catalogs
Oral Session – National Harbor 5 – 08 Jan 2014 10:00 am to 11:30 am

302.01 – Using Cloud Computing To Create A Multi-Wavelength Atlas Of The Galactic Plane

G. B. Berriman[1], John Good[1], Mats Rynge[2], Gideon Juve[2], Ewa Deelman[2], Jamie Kinney[3], Ann Merrihew[3]
1. Caltech, Pasadena, CA, United States. 2. Information Sciences Institute, USC, Marina del Rey, CA, United States. 3. Amazon Web Services, Seattle, WA, United States.

We describe by example how to optimize cloud-computing resources offered by Amazon Web Services (AWS) to create and curate new datasets at scale. We are producing a co-registered atlas of the Galactic Plane at 16 wavelengths from 1 micron to 24 microns with a spatial sampling of 1 arcsec. The atlas is being created by using the Montage mosaic engine to generate co-registered mosaics of images released by the major surveys WISE, 2MASS, ADASS, GLIMPSE and MIPSGAL. The Atlas, when complete, will be 45 TB in size, composed of over 9,600 5 deg x 5 deg tiles with one degree overlap between them. The dataset will be housed on Amazon S3, designed for at-scale storage with access via web protocols. It will be publicly accessible through an API that will support access to the data and creation of cutouts according to the users' specifications. The processing, which is estimated to require 340,000 compute hours for completion, has exploited virtual clusters created and managed on AWS platforms through the Pegasus workflow management system. We will describe the optimization methods, compute time and processing costs, as a guide for others wishing to exploit cloud platforms for processing and data creation.

302.02 – Noise characteristics of LCOGT time series photometry

Diana Dragomir[1], Timothy M. Brown[1]
1. LCOGT/UCSB, Santa Barbara, CA, United States.

The Las Cumbres Observatory Global Telescope (LCOGT) facility consists of a network of robotic telescopes located at multiple sites in both the northern and southern hemispheres. We have deployed and commissioned nine 1.0m telescopes. Eight of these are distributed longitudinally at three sites to provide continuous night-time coverage in the south. LCOGT's unique capabilities can contribute to a wide range of research in the field of time-domain astronomy. To ensure optimal data quality for individual as well as combined multi-telescope time series, it is essential that we understand and correct - whenever possible - the instrument systematics affecting LCOGT network observations. We identify physical sources of noise present in LCOGT 1.0m photometry, and we use singular value decomposition (SVD) to filter correlated noise patterns common to an ensemble of stars in a given time series data set. We quantify and compare the levels of uncorrelated and correlated noise before and after SVD filtering using power spectral analysis. Finally, we discuss the properties of and methods to reduce any remaining post-SVD red noise that is due to instrumental systematics.

302.03 – The Astrophysical Multimessenger Observatory Network (AMON)

Gordana Tešic[1]
1. The Pennsylvania State University, University Park, PA, United States.
Contributing teams: AMON development team

The Astrophysical Multimessenger Observatory Network (AMON) aims to use the messenger particles of all four fundamental forces in order to discover high-energy transient phenomena that would be extremely difficult to detect by any single observatory alone. AMON will link together several current and future high-energy (neutrino, cosmic and gamma-ray) and gravitational wave observatories into a single system with higher combined sensitivity than that of any participating experiment alone. We present the design elements, current and projected partner observatories, the anticipated science return and discovery potential of the AMON network.

302.04 – Explosive Growth and Advancement of the NASA/IPAC Extragalactic Database (NED)

Joseph M. Mazzarella[1], Patrick M. Ogle[1], Dario Fadda[1], Barry F. Madore[1], Rick Ebert[1], Kay Baker[1], Hiu Pan Chan[1], Xi Chen[1], Cren Frayer[1], George Helou[1], Jeffery D. Jacobson[1], Cheryl LaGue[1], Tak M. Lo[1], Olga Pevunova[1], Marion Schmitz[1], Scott Terek[1], Ian Steer[2]
1. Caltech, Pasadena, CA, United States. 2. Toronto, Toronto, ON, Canada.

The NASA/IPAC Extragalactic Database (NED) is continuing to evolve in lock-step with the explosive growth of astronomical data and advancements in information technology. A new methodology is being used to fuse data from very large surveys. Selected parameters are first loaded into a new database layer and made available in areal searches before they are cross-

matched with prior NED objects. Then a programmed, rule-based statistical approach is used to identify new objects and compute cross-identifications with existing objects where possible; otherwise associations between objects are derived based on positional uncertainties or spatial resolution differences. Approximately 62 million UV sources from the GALEX All-Sky Survey and Medium Imaging Survey catalogs have been integrated into NED using this new process. The December 2013 release also contains nearly half a billion sources from the 2MASS Point Source Catalog accessible in cone searches, while the large scale cross-matching is in progress. Forthcoming updates will fuse data from All-WISE, SDSS DR12, and other very large catalogs. This work is progressing in parallel with the equally important integration of data from the literature, which is also growing rapidly. Recent updates have also included H I and CO channel maps (data cubes), as well as substantial growth in redshifts, classifications, photometry, spectra and redshift-independent distances. The By Parameters search engine now incorporates a simplified form for entry of constraints, and support for long-running queries with machine-readable output. A new tool for exploring the environments of galaxies with measured radial velocities includes informative graphics and a method to assess the incompleteness of redshift measurements. The NED user interface is also undergoing a major transformation, providing more streamlined navigation and searching, and a modern development framework for future enhancements. For further information, please visit our poster (Fadda et al. 2014) and stop by the NED exhibit for a demo. NED is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

302.05 – Best Practices for Data Publication to Facilitate Integration into NED: A Reference Guide for Authors

Marion Schmitz[1], Joseph M. Mazzarella[1], Barry F. Madore[1], Patrick M. Ogle[1], Rick Ebert[1], Kay Baker[1], Hiu Pan Chan[1], Xi Chen[1], Dario Fadda[1], Cren Frayer[1], Jeffery D. Jacobson[1], Cheryl LaGue[1], Tak M. Lo[1], Olga Pevunova[1], Scott Terek[1], Ian Steer[2]
1. Caltech, Pasadena, CA, United States. 2. Self, Toronto, ON, Canada.

At the urging of the NASA/IPAC Extragalactic Database (NED) Users Committee, the NED Team has prepared and published on its website a new document titled "Best Practices for Data Publication to Facilitate Integration into NED: A Reference Guide for Authors". (http://ned.ipac.caltech.edu/docs/BPDP/NED_BPDP.pdf) We hope that journal publishers will incorporate links to this living document in their Instructions to Authors to provide a practical reference for authors, referees, and science editors so as to help avoid various pitfalls that often impede the interpretation of data and metadata, and also delay their integration into NED, SIMBAD, ADS and other systems. In particular, we discuss the importance of using proper naming conventions, providing the epoch and system of coordinates, including units and uncertainties, and giving sufficient metadata for the unambiguous interpretation of tabular, imaging, and spectral data. The biggest impediments to the assimilation of new data from the literature into NED are ambiguous object names and non-unique, coordinate-based identifiers. A Checklist of Recommendations will be presented which includes links to sections of the Best Practices document that provide further examples, explanation, and rationale.

302.06 – Using WorldWide Telescope in Observing, Research and Presentation

Douglas A. Roberts[1], Jonathan Fay[1]
1. Northwestern University, Evanston, IL, United States.

WorldWide Telescope (WWT) is free software that enables researchers to interactively explore observational data using a user-friendly interface. Reference, all-sky datasets and pointed observations are available as layers along with the ability to easily overlay additional FITS images and catalog data. Connections to the Astrophysics Data System (ADS) are included which enable visual investigation using WWT to drive document searches in ADS. WWT can be used to capture and share visual exploration with colleagues during observational planning and analysis. Finally, researchers can use WorldWide Telescope to create videos for professional, education and outreach presentations. I will conclude with an example of how I have used WWT in a research project. Specifically, I will discuss how WorldWide Telescope helped our group to prepare for radio observations and following them, in the analysis of multi-wavelength data taken in the inner parsec of the Galaxy. A concluding video will show how WWT brought together disparate datasets in a unified interactive visualization environment.

302.07 – Enhancing Science with the Hubble Source Catalog

Bradley C. Whitmore[1], Sahar S. Allam[1], Tamas Budavari[2, 1], Stefano Casertano[1], Stephen H. Lubow[1], Lee Quick[1], Louis-Gregory Strolger[1], Richard L. White[1]
1. STScI, Baltimore, MD, United States. 2. Johns Hopkins University, Baltimore, MD, United States.

The Hubble Source Catalog (HSC) is an initiative to combine the tens of thousands of visit-based Hubble Legacy Archive (HLA - available at http://hla.stsci.edu) source lists into a single master catalog. The HSC currently includes ACS/WFC, WFPC2, and WFC3 source lists generated using the Source Extractor (Bertin & Arnouts 1996) software, and a cross-matching technique described in Budavari & Lubow (2012). The astrometric residuals for the HCS individual objects are typically within 10 mas. The talk will focus on the development of several detailed use cases that demonstrate both the

quality of the data in the HSC and some of its current limitations that users should be aware of. We are currently in the Beta 0.3 stage of development with plans for Version 1 (i.e., improved WFPC2 and ACS sources lists, better matching and enhanced tools including a CASJOBS capability) in the summer of 2014. Demonstrations will be provided at the Space Telescope Science Institute booth during the conference and people will have the opportunity to use the system interactively. We are also looking for people that are interested in joining our HSC Working Group that helps develop use cases and tests new capabilities as they are developed. The url for the HSC is http://archive.stsci.edu/hst/hsc/

302.08D – Combing Large Samples of Type Ia Supernovae To Constrain Dark Energy

Daniel Scolnic[1], Adam G. Riess[1, 2]
1. Johns Hopkins University, Baltimore, MD, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: PS1 Transients Group

SNe Ia remain one of the best tools to determine whether the dark energy is a static, cosmological constant (w(z) = -1) in the local volume because they can be discovered in large sample sizes and their individual measurement precision is high. Future progress in this field depends on solving two questions: how to reduce the nearly-dominant systematic uncertainties in SN Ia distance measurements, and how to take advantage of the 100-1000x more supernovae that will be found in the next ten years for which we cannot follow-up with spectroscopy. This thesis addresses both of these efforts. One of the largest systematic uncertainties in using SNIa measurements as a cosmological probe has been how to understand the diversity of SNIa color. We discuss how there is a degeneracy between models in which SNIa color is and is not consistent with a Milky Way reddening law. Misattribution of the source of SNIa color leads to significant biases (~5%) in our measurements of the equation-of-state of dark energy. We review our derived cosmological parameters with the Pan-STARRS supernova sample, and discuss the limiting systematic uncertainties (e.g., calibration, supernova color, dependence on host properties, Milky Way extinction, coherent flows). This sample is one of the largest analyzed samples of SNIa and we show how many of the uncertainties may be reduced for future surveys like DES and LSST. To address the question of how to benefit from the orders of magnitude more supernova discoveries, we propose a method of SN observation using 'comb' filters with narrow passbands on a single substrate to retain the speed of photometric observations with most of the accuracy of spectroscopic observations. This approach determines the type of SN and for SNe Ia, their redshifts. We discuss how we use this `SNACC' method to more fully harvest the yield expected from large-scale SN surveys. We find that we can achieve a sample with >90% high purity and redshift accuracy to dz~0.01.

303 – Debris Disks Around Young Stars and Planet Formation I

Oral Session – Potomac Ballroom C – 08 Jan 2014 10:00 am to 11:30 am

303.01 – SMACK: A New Algorithm for Modeling Collisions and Dynamics of Planetesimals in Debris Disks

Erika Nesvold[1], Marc J. Kuchner[2], Hanno Rein[3, 4], Margaret Pan[2]
1. University of Maryland, Baltimore County, Baltimore, MD, United States. 2. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 3. Institute for Advanced Study, Princeton, NJ, United States. 4. University of Toronto Scarborough, Toronto, ON, Canada.

We present the Superparticle Model/Algorithm for Collisions in Kuiper belts and debris disks (SMACK), a new method for simultaneously modeling, in 3-D, the collisional and dynamical evolution of planetesimals in a debris disk with planets. SMACK can simulate azimuthal asymmetries and how these asymmetries evolve over time. We show that SMACK is stable to numerical viscosity and numerical heating over 10^7 yr, and that it can reproduce analytic models of disk evolution. We use SMACK to model the evolution of a debris ring containing a planet on an eccentric orbit. Differential precession creates a spiral structure as the ring evolves, but collisions subsequently break up the spiral, leaving a narrower eccentric ring.

303.02D – A Multi-Wavelength Study of Grain Growth in Protoplanetary Disks

Catarina Ubach[1]
1. Swinburne University, Melbourne, VIC, Australia.

Protoplanetary disk around young stellar objects contain the building blocks of planets. Observations at millimeter wavelengths are used to directly probe the cooler outer regions and mid-plane of the disk where the bulk of the dust resides. Observations at 1 and 3 mm can provide signatures of growth to mm-sized grains. Signatures of grains up to cm sizes can only be obtained by increasing the observing wavelength to 7 and 15 mm. If thermal dust emission dominates at 7 mm and beyond, the spectral slope should remain constant into the cm bands. However, as the observing wavelength is increased from 3 to 7 and 15 mm, other forms of emission besides thermal dust emission can also be present. The contributions from other processes cause an excess in flux above the expected thermal dust emission, and thus disentangling the emission mechanisms is required before conclusions can be made about the maximum grain size. We present results of our Australia Telescope Compact Array 3 and 7 mm continuum survey of 20 T Tauri stars, which aims to identify protoplanetary disks with signs of grain growth and temporal monitoring results of a sub-set of sources at 7, 15 mm and 3+6 cm to investigate grain growth up to cm sizes and disentangle the emission mechanisms present in these sources. We found 11 sources have dominant thermal dust emission up to 7 mm, with 7 of these having a 1-3 mm dust opacity index < 1, suggesting grain growth up to at least mm sizes. Sources observed at 15 mm and beyond show the presence of excess emission from multiple emission mechanisms. Long timescale monitoring at 7 mm indicates that cm-sized pebbles are present in at least 4 sources, while short timescale monitoring at 15 mm suggests the excess emission is from thermal free-free emission. These results provide evidence that grain growth up to cm-sized pebbles and the presence of excess emission at 7 mm and beyond are common in these systems, and to disentangle the thermal dust emission from other contributing emission mechanisms one needs to conduct temporal flux monitoring across a range of timescales. It also provides evidence that the large grain population can have a significant contribution to the emission at the longer mm wavelengths.

303.03 – The Migrating Embryo Model for Planet Formation

Shantanu Basu[1], Eduard Vorobyov[2]
1. Western University, London, ON, Canada. 2. The University of Vienna, Vienna, Austria.

A new view of disk evolution and planet formation is emerging from self-consistent numerical simulation modeling of the formation of circumstellar disks from the direct collapse of prestellar cloud cores. A defining result is that the early evolution of a disk is crucially affected by the continuing mass loading from the core envelope, with recurrent phases of gravitational instability occurring in the disk. Nonlinear spiral arms formed during these episodes fragment to form gaseous clumps. These clumps generally migrate inward due to gravitational torques arising from their interaction with a trailing spiral arm. Occasionally, a clump can open up a gap in the disk and settle into a stable orbit, revealing a direct pathway to the formation of companion stars, brown dwarfs, or giant planets. At other times, when multiple clumps are present, a low mass clump may even be ejected from the system, providing a pathway to the formation of free-floating brown dwarfs and giant planets in addition to low mass stars. Finally, the inward migration of gaseous clumps may provide the proper conditions for the transport of high-temperature processed solids from the outer disk to the inner disk, and even possibly accelerate the formation of terrestrial planets in the inner disk. All of these features arising from clump formation and migration can be tied together conceptually in a migrating embryo model that can complement the well-known core accretion model for planet formation.

303.04D – Evolution of Protoplanetary Disks in the Orion A Star-Forming Region

Kyoung Hee Kim[1, 2]
1. Univ. Of Rochester, Rochester, NY, United States. 2. Korea Astronomy and Space Science Institute, Daejeon, Korea, Republic of.

We present our investigation of the characteristics of Class II protoplanetary disks in Orion A star-forming region. Our major goal is to analyze a large sample of protoplanetary disks with near- and mid-IR spectra, by statistical approaches, to understand protoplanetary disk evolution in Orion A. For this work, 303 protoplanetary disks in Orion A region observed by IRS/Spitzer and the follow-up observation of 120 objects from SpeX/IRTF are used to reveal the characteristics of Class II disks in Orion A. For clues on environmental effects on disk evolution and planet formation, we compare the disk properties and dust properties of Orion A disks to that of Taurus disks and examine trends with respect to position within Orion A. We extract spectral indices, equivalent widths, and integrated fluxes from IRS spectra of Class II objects in Orion A which pertain to disk structure and dust composition. We measure mass accretion rates using hydrogen recombination lines in SpeX spectra of our targets. Utilizing the properties, we analyze the general distribution of properties of disks in ONC, L1641, and Taurus from their histograms. Our main findings are as follows. (1) From the high frequency (>20%) of transitional disks and the similar vertical structure of the Orion A disks to those of Taurus, we infer that giant planet formation and dust sedimentation is well under way, if not complete, even in the youngest Class II objects. (2) Less grain processing – crystallization and growth of grains to diameter of 1–10 μm – has occurred among the dust grains in the Orion A disks than in Taurus. The time scales for dust processing must therefore lie in the range of ages of the nearby clouds like Orion, NGC 1333, Taurus, Ophiuchus and Chamaeleon. (3) We detected PAH emission at 6–14 μm from disks around low-mass and low-luminosity young stars, excited externally by UV from the Trapezium stars. (4) As others have found for the Trapezium region of Orion, the disks of the surrounding Orion Nebular Cluster suffer reduced emission at long infrared wavelengths. The reduction tracks distance from the most luminous Trapezium star, Theta-1 Ori C, so this appears to be the effect of UV oblation of the outer part of the disks.

303.05D – High-Contrast Near-Infrared Imaging and Modeling of Planets and Debris Disks

Timothy Rodigas[1, 2], Philip Hinz[2], Alycia J. Weinberger[1], Laird M. Close[2], John H. Debes[3]
1. Carnegie DTM, Washington, DC, United States. 2. University of Arizona, Tucson, AZ, United States. 3. STSCI, Baltimore, MD, United States.

Planets are thought to form in circumstellar disks, leaving behind planetesimals that collide to produce dusty debris disks. Characterizing the architectures of planetary systems, along with the structures and compositions of debris disks, can therefore help answer questions about how planets form. In this talk, I will present the results of five papers concerning the properties of extrasolar planetary systems and their circumstellar environments. First I will discuss bias affecting radial velocity (RV) orbital eccentricity. For years astronomers have been puzzled about the large number of RV-detected planets that have eccentric orbits (e > 0.1). I will show that this problem can partially be explained by showing that two circular-orbit planets can masquerade as a single planet on an eccentric orbit. I use this finding to predict that planets with mildly eccentric orbits are the most likely to have massive companions on wide orbits, potentially detectable by future direct imaging observations. Next I will present recent high-contrast 2-4 μm imaging studies of the edge-on debris disks around HD 15115 and HD 32297. HD 15115's color is found to be gray, implying large grains 1-10 μm in size reside in stable orbits in the disk. HD 32297's disk color is red from 1-4 μm. Cometary material (carbon, silicates, and porous water ice) are a good match at 1-2 μm but not at L?. Tholins, organic material that is found in outer solar system bodies, or small silicates can explain the disk's red color but not the short wavelength data. I will then present my work on the dynamics of dust grains in the presence of massive planets. I will show that the width of a debris disk increases proportionally with the mass of its shepherding planet. I use this result to make predictions for the masses and orbits of putative planets in five well-known disks. Finally, I will present recent MagAO/Clio near-infrared imaging results on the debris disk around HR4796A spanning the 0.5-4 um wavelength range. These images reveal the disk at unprecedented detail, allowing detailed compositional and morphological modeling of the dust.

303.06 – HD 181327 Debris Disk Asymmetries: Signs of a Planet or Geometric Projection Effects?

Christopher C. Stark[1], Glenn Schneider[5], Alycia J. Weinberger[2], John H. Debes[3], Hannah Jang-Condell[4], Carol A. Grady[1], Joseph Carson[12], Thomas Henning[9], Dean C. Hines[3], Phil Hinz[5], Marc J. Kuchner[1], Amaya Moro-Martin[10], Marshall D. Perrin[3], Motohide Tamura[8], Gene Serabyn[6], Murray D. Silverstone[11], Miwa Goto[7], John P. Wisniewski[13]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 2. Carnegie Institution of Washington, Washington, DC, United States. 3. Space Telescope Science Institute, Baltimore, MD, United States. 4. University of Wyoming, Laramie, WY, United States. 5. University of Arizona, Tucson, AZ, United States. 6. NASA JPL, Pasadena, CA, United States. 7. Universitäts-Sternwarte München, Munich, Germany. 8. National Astronomical Observatory of Japan, Tokyo, Japan. 9.

Max-Planck-Institut für Astronomie, Heidelberg, Germany. 10. Instituto Nacional de Técnica Aeroespacial, Madrid, Spain. 11. University of Alabama, Tuscaloosa, AL, United States. 12. College of Charleston, Charleston, SC, United States. 13. University of Oklahoma, Norman, OK, United States.

We present new Hubble Space Telescope (HST) observations of the HD 181327 debris disk using the Space Telescope Imaging Spectrograph (STIS). Our multi-roll coronagraphic image, combined with new multi-roll image processing techniques, reveals the outer debris ring in its entirety at high SNR. The disk exhibits several significant asymmetries that, at first glance, appear to suggest the presence of a planet. We use new image deprojection methods to constrain the true disk geometry, measure an empirical scattering phase function, and show that the majority of these asymmetries are consistent with scattering and line-of-sight projection effects. One asymmetry, a "post-pericenter glow," appears to be a true density enhancement and we speculate on the origin of this density asymmetry.

304 – Demographic Studies and the AAS

Special Session – National Harbor 3 – 08 Jan 2014 10:00 am to 11:30 am

In its report, the 2010 Decadal Survey (New Worlds New Horizons) recommended that the American Astronomical Society, the American Physical Society, astronomy and astrophysics departments, and federal agencies should gather and disseminate demographic data on astronomers in the workforce to provide students information about career choices. The same report noted that minority Americans continue to be seriously underrepresented in the profession. To promote and increase the numbers of minorities, and promote gender equity, it is important to know what factors affect entry and retention into astronomy and astrophysics. Hence, in this special session, sponsored by the AAS Demographics Committee, the focus is on how demographic information can help address both workforce and representation issues. Debbie Elmegreen will discuss the importance of demographic studies for the profession and to the 2010 Decadal Survey. Marc Postman will present the AAS Workforce Survey, Pat Knezek will discuss why a Longitudinal Survey is important, and Rachel Ivie will present results to date from the Longitudinal Survey.

304.01 – The Importance of Demographic Data in Astronomy

Debra M. Elmegreen[1]
1. Vassar College, Poughkeepsie, NY, United States.

The most effective astronomical workforce will be one that comprises a diverse and inclusive community. The "New Worlds, New Horizons in Astronomy and Astrophysics" Decadal Survey, with input from its Infrastructure Study Group on Demographics, provided an overview of recent demographic trends. Demographics in astronomy have undergone significant changes over the past two generations in several, but not all, categories. Maintaining records of demographics regarding age, gender, and minority status, as well as trends by discipline and career choices, is vital in planning for the future training and employment of astronomers.

304.02 – The AAS Workforce Survey

Marc Postman[1], Dara J. Norman[3], Nancy R. Evans[2], Rachel Ivie[4]
1. STScI, Baltimore, MD, United States. 2. Center for Astrophysics, Cambridge, MA, United States.
3. NOAO, Tucson, AZ, United States. 4. AIP, College Park, MD, United States.

The AAS Demographics Committee, on behalf of the AAS, was tasked with initiating a biennial survey to improve the Society's ability to serve its members and to inform the community about changes in the community's demographics. A survey, based in part on similar surveys for other scientific societies, was developed in the summer of 2012 and was publicly launched in January 2013. The survey randomly targeted 2500 astronomers who are members of the AAS. The survey was closed 4 months later (April 2013). The response rate was excellent – 63% (1583 people) completed the survey. I will summarize the results from this survey, highlighting key results and plans for their broad dissemination.

304.03 – Results from the Longitudinal Study of Astronomy Graduate Students

Rachel Ivie[1]
1. AIP, College Park, MD, United States.

The Longitudinal Study of Astronomy Graduate Students (LSAGS), an ongoing, joint project of the American Astronomical Society (AAS) and the American Institute of Physics (AIP), first collected survey data from astronomy and astrophysics graduate students in 2007-08. The LSAGS follows the same people, all of whom were in graduate school in 2006-07, over time as they start their careers. Most of the respondents are currently working as postdocs. There have been two rounds of the survey so far, and we have recently received funding for a third round from the National Science Foundation (AST-1347723). Results from the first round showed the importance of mentoring for graduate students. Data collection for the second round has been completed, and AIP has just begun analysis of these data. At this talk, I will present the results of the second survey. Ultimately, the LSAGS will *provide detailed data on trends in employment over 10+ years for a single cohort, *collect data on people who leave the field of astronomy during or after graduate school, *determine whether there are sex differences in attrition from astronomy and reasons for this, and *examine factors that precede decisions to persist in, or leave, the field of astronomy.

304.04 – The Importance of Longitudinal Studies

Patricia Knezek[1]
1. NSF, Arlington, VA, United States.

It has been eight years since the AAS Council unanimously endorsed the document, known as "Equity Now: The Pasadena Recommendations for Gender Equality in Astronomy," in January 2005. This document was the main product of the conference entitled "Women in Astronomy II: Ten Years After" (WIA II), held in June 2003 in Pasadena, CA. One of the key recommendations represented in that document was the need for a longitudinal study of astronomers. It was recognized that

in order to understand our own field, how it is evolving, and the impact on individuals, we need to track people over time. I will discuss the fundamental questions that led to the recommendation, and set the stage for the current (ongoing) longitudinal study.

305 – Developing Career Opportunities in Science Policy and Industry at All Career Levels

Special Session – National Harbor 2 – 08 Jan 2014 10:00 am to 11:30 am

The AAS Employment Committee will host a panel discussion on career opportunities beyond academia, focusing on several possibilities that can be explored through fellowships and temporary positions, particularly in science policy/administration and industry. Short term fellowships, internships, and temporary assignments are excellent ways to explore potential careers, and to gain the experience and make the connections that enable career transitions at all career levels. The goals of the session are to provide information on the ways to become involved in these kinds of positions and on the career benefit they bring, and to open a dialog with the community about how they can be incorporated in current educational programs. The panel will feature speakers with a variety of backgrounds in astronomy, and whose diverse experiences will offer a range of perspectives on how one can become involved in science policy, industry, and other areas outside of academic or research positions. There will be ample opportunity for audience questions and discussion with panel members.

307 – Evolution of Local Group Galaxies
Oral Session – Maryland Ballroom C – 08 Jan 2014 10:00 am to 11:30 am

307.02D – Exploiting Large Multi-element Stellar Abundance Surveys

Brett Andrews[1]

1. The Ohio State University, Columbus, OH, United States.

The next generation of stellar abundance surveys, such as APOGEE, APOGEE-2, GALAH, and Gaia-ESO, will measure the abundances of 10-30 elements for more than 100,000 stars, a significant improvement over existing datasets. To maximize the information extracted from these rich datasets, we have adopted a two-pronged approach. First, we are developing advanced statistical techniques, like Principal Component Abundance Analysis (PCAA), to characterize the distribution of stars in multi-element abundance space. PCAA can be used to quantify the number of independent dimensions in abundance space, assess the importance of stochastic processes, classify stellar populations, find outliers, and identify nucleosynthetic pathways. When we applied PCAA to a sample of microlensed bulge dwarf stars and a comparison sample of local disk stars, the first principal component of each population reflected the correlation amongst alpha-element abundances. The second principal component of the bulge stars revealed a Na-Ni correlation, indicative of metallicity-dependent Type II supernova yields; however, the second principal component of the disk stars showed a Y-Ba correlation, a consequence of enrichment from asymptotic giant branch stars. For the second aspect of our investigation, we have constructed a flexible chemical evolution model to produce simulated abundances for a wide range of galaxy evolution parameters. Rather than simply reproducing the mean observed abundance trends, we explicitly highlight the generic failures of chemical evolution models, the degeneracies between different galaxy evolution parameters, and the causes of scatter in the simulated abundances. Advanced data-driven modeling of stellar abundances and detailed chemical evolution models will prove invaluable for understanding the role of galaxy formation processes in shaping stellar abundance patterns.

307.03D – Clouds of neutral hydrogen between M31 and M33 and around the Milky Way.

Spencer A. Wolfe[1], Daniel J. Pisano[1], Felix J. Lockman[2], Stacy S. McGaugh[3], Edward J. Shaya[4]

1. West Virginia University, Morgantown, WV, United States. 2. National Radio Astronomy Observatory, Green Bank, WV, United States. 3. Case Western Reserve University, Cleveland, OH, United States. 4. University of Maryland, College Park, MD, United States.

Large spiral galaxies like our own Milky Way must acquire fresh gas to continue forming new stars. The gas that resides between galaxies may be a source of this material, but we know little about the gas' structure or extent. I will present my thesis research, which attempts to answer these questions, based on our Green Bank Telescope (GBT) observations of the very faint M31-M33 neutral hydrogen (HI) stream that was first discovered a decade ago using the Westerbork Synthesis Radio Telescope. Our spectral line observations have over five times higher spatial resolution and roughly three times higher velocity resolution than the Westerbork data. These are the most sensitive observations of the 21 cm line conducted with the GBT. I will discuss our observing and reduction techniques used to reach the sensitivities needed to study the HI stream in detail. We find that the gas is actually composed of small clouds only a few kiloparsecs in diameter. The kinematics of the clouds also suggests that they are associated with M31 and M33 and not each galaxy's respective High Velocity Cloud (HVC) population. Most, if not all, of the clouds do not appear to have stars associated with them. Thus, we believe that these clouds are part of a condensing intergalactic filament and may be a source of future star formation for M31 and M33. In addition, I will briefly present my research on the High Velocity and Intermediate Velocity Clouds around our Milky Way using the Galactic All-Sky Survey (GASS) at 21 cm that was conducted with the Parkes 64m radio telescope. I will discuss the basic properties of this gas and some interesting features seen in the survey.

307.04 – NANOGrav and the Astrophysics of Galaxies

Fredrick Jenet[1, 2]

1. Univ. of Texas at Brownsville, Brownsville, TX, United States. 2. Center for Advanced Radio Astronomy, Brownsville, TX, United States.

Contributing teams: NANOGrav

Observations of low-frequency gravitational waves have the potential to reveal important information about the evolution and interaction of galaxies through the detection of supermassive black hole binaries. NANOGrav, the North American NanoHertz Observatory for Gravitational Waves, is developing techniques to detect and study such gravitational waves through pulsar timing. These techniques are sensitive to gravitational waves from both the superposition of many sources and from individual sources. This talk will give an overview of the NANOGrav collaboration and its international partners and review the current status of the field, with emphasis on how NANOGrav observations will help us to understand the astrophysics of galaxies.

308 – Exoplanets: Interiors, Evolution, and planetarydisks

Oral Session – Maryland Ballroom A – 08 Jan 2014 10:00 am to 11:30 am

308.01D – Circumplanetary Debris Disks in the Solar System and Beyond: Is the Fomalhaut System on the Verge of a Late Heavy Bombardment?

Daniel Tamayo[1], Joseph A. Burns[1]
1. Cornell University, Ithaca, NY, United States.

Each of the Solar System's giant planets hosts many small and distant irregular satellites. These moons' radially overlapping orbits and their unusually shallow size distributions imply a violent collisional history (Bottke et al. 2010). Thus, at early epochs, the giant planets likely displayed prominent circumplanetary debris clouds. For my PhD I numerically studied how such debris in the Saturnian system would evolve inward through radiation forces to coat the striking two-faced moon Iapetus (Tamayo et al. 2011). I also investigated the analogous process at Uranus, where the planet's extreme obliquity renders infalling dust orbits chaotic. We find that this could explain the color dichotomies observed on the largest four Uranian satellites (Tamayo et al 2013a, 2013b). Even today, Saturn has such a vast dust disk, sourced by the irregular satellite Phoebe (Verbiscer et al. 2009). This 'Phoebe Ring', can be used to observationally study the gravitational effects of moons on the dust; I have successfully probed this ring with Cassini, but was unsuccessful with Herschel observations. By these combined observational and dynamical studies, I hope to inform the field of extrasolar debris disks, where one tries to use dust signatures to infer the existence of planets that are too faint to see. I am now focusing on a related problem involving the exoplanet candidate Fomalhaut b (Kalas et al. 2008). While its optical flux is too large to come directly from a planet, perhaps we are observing a disk supplied by irregular moons like the Phoebe Ring(Kennedy & Wyatt 2011). Additional observation epochs imply that Fomalhaut-b's orbit is very eccentric (Kalas et al. 2013). Yet despite crossing the system's observed circumstellar debris disk in projection, Fomalhaut b does not appear to have significantly disturbed it. We argue from simulations that if Fomalhaut b is a giant planet, it must have scattered into its present orbit in the past ~10 Myr. Furthermore, if it is the only object dynamically interacting with the belt, the debris disk's eccentricity will continue rising to values near unity, perhaps causing an event analogous to the Late Heavy Bombardment hypothesized to have occurred in the early Solar System.

308.02D – Protoplanetary Disks on a Moving Mesh, and other applications.

Paul Duffell[1]
1. New York University, New York, NY, United States.

In integrating the equations of magnetohydrodynamics, standard numerical techniques are very powerful at shock-capturing, but use a fixed grid, allowing fluid to be passed from grid cell to grid cell. New numerical methods have emerged over the past few years which perform calculations on a more generalized mesh, allowing the grid to move with the flow, but while still preserving the desired shock-capturing properties of fixed-grid methods. The most well-known of these methods uses a Voronoi Tessellation to dynamically re-calculate the shape and size of computational zones as the move through the domain. I will discuss several implementations of such grids, with applications to protoplanetary disks, black hole binary systems, tidal disruption events, binary mergers, and relativistic jets.

308.03 – Particle Trapping in the Outer Regions of Protoplanetary Disks

Jacob B. Simon[1, 2], Philip J. Armitage[3]
1. Sagan Fellow, Boulder, CO, United States. 2. Sagan Fellow, Southwest Research Institute, Boulder, CO, United States. 3. University of Colorado, Boulder, CO, United States.

I will discuss the formation and strength of axisymmetric local pressure maxima (zonal flows) in the outer regions of protoplanetary disks, where ambipolar diffusion reduces turbulent stresses driven by the magnetorotational instability. Zonal flows are a candidate mechanism for slowing the radial drift of solids and concentrating particles, a prelude to planetesimal formation. Using local numerical simulations, I will show that zonal flows in the outer disk can be strong enough to trap particles, provided that the turbulence generates enough vertically integrated stress to account for measured stellar accretion rates. In the presence of ambipolar diffusion, this requires a weak vertical magnetic field. Without such a field, particle trapping is unlikely to occur.

308.04 – Interior structure of solid super-Earths: temperature-dependent H2O structure and new online tools

Li Zeng[1], Dimitar D. Sasselov[1]
1. Harvard University, Cambridge, MA, United States.

With the ongoing effort, more and more Earth-sized and SuperEarth-sized planets are being discovered. We speculate some of them contain a significant mass fraction of H2O, the so-called water worlds. The H2O could be subject to ultra-high

pressure underneath thousands of kilometers of material on top. Therefore, it is interesting to find out the possible states of H2O on those planets, and what happens when the planet's interior cools down. Online tools, model grids, and tables, are available on (www.astrozeng.com), to interpret the bulk composition of exoplanets.

308.05 – Giant-Planet Structure and Evolution, and Its Dependence on Atmospheric and Interior Thermal Processes

David S. Spiegel[1], Adam S. Burrows[2]
1. Institute for Advanced Study, Princeton, NJ, United States. 2. Princeton University, Princeton, NJ, United States.

We explore the influences on gas-giant radius evolution of both the initial heat content and of a variety of types of thermal processes in the atmosphere and the deep interior. In particular, we compare the radius-expansion effects of atmospheric and deep-interior heating at the same power levels and derive the power required to achieve a given radius increase when night-side cooling is incorporated. We find that models that include consistent day/night cooling are more similar to isotropically irradiated models when there is more heat redistributed from the dayside to the nightside, and that, when taking night-side cooling into account, it might be impossible to explain the radii of very highly inflated hot Jupiters without invoking extra power sources in the deep interior.

308.06 – Uneven Cooling: The Influence of Differential Heating and Circulation on the Thermal Evolution of Gas Giants

Emily Rauscher[1], Adam P. Showman[2]
1. Princeton University, Princeton, NJ, United States. 2. Univ. of Arizona, Tucson, AZ, United States.

As a planet ages it cools and its radius shrinks, at a rate set by the efficiency with which heat is transported from the interior out to space. The bottleneck for this transport is at the boundary between the convective interior and the radiative atmosphere; the opacity there sets the global cooling rate. Models of planetary evolution are often one-dimensional, such that the radiative-convective boundary (RCB) is defined by a single temperature, pressure, and opacity. In reality the spatially inhomogenous stellar heating pattern and circulation in the atmosphere could deform the RCB, allowing heat from the interior to escape more efficiently through regions with lower opacity. We present an analysis of the degree to which the RCB could be deformed and the resultant change in the evolutionary cooling rate. In this initial work we calculate the upper limit for this effect by comparing an atmospheric structure in local radiative equilibrium to its 1D equivalent. We find that the cooling through an uneven RCB could be enhanced over cooling through a uniform RCB by as much as 10-50%. We also show that the deformation of the RCB (and the enhancement of the cooling rate) increases with a greater incident stellar flux or a lower inner entropy. Our results indicate that this mechanism could significantly change a planet's thermal evolution, causing it to cool and shrink more quickly than would otherwise be expected. This may exacerbate the well known difficulty in explaining the very large radii observed for some hot Jupiters.

309 – Galaxies I - Motions, Velocities, Kinematics, Masses

Oral Session – National Harbor 12 – 08 Jan 2014 10:00 am to 11:30 am

309.01 – The Steeply Rising Stellar Velocity Dispersion of M87 from Integrated Starlight

Jeremy Murphy[1], Karl Gebhardt[2]

1. Princeton University, Princeton, NJ, United States. 2. University of Texas, Austin, TX, United States.

We have measured the line-of-sight velocity distribution from integrated stellar light at two points in the outer halo of M87 (NGC 4486), the second-rank galaxy in the Virgo Cluster. The data were taken at R = 480" (~ 41.5 kpc) and R = 526" (~ 45.5 kpc) along the SE major axis. The second moment for a non-parametric estimate of the full velocity distribution is 420 +/- 23 and 577 +/- 35 km/s respectively. There is intriguing evidence in the velocity profiles for two kinematically distinct stellar components at the position of our pointing. Under this assumption we employ a two-Gaussian decomposition and find the primary Gaussian having rest velocities equal to M87 (consistent with zero rotation) and second moments of 383 +\- 32 and 446 +\- 43 km/s respectively. The asymmetry seen in the velocity profiles suggests that the center of the Virgo Cluster is not in a relaxed state and confuses a clean dynamical interpretation. That said, either measurement (full or two component model) shows a rising velocity dispersion at large radii, consistent with previous integrated light measurements, yet significantly higher than globular cluster and planetary nebulae measurements at comparable radial positions. These integrated-light measurements at large radii, and the stark contrast they make to the measurements of other kinematic tracers, highlight the rich kinematic complexity of environments like the center of the Virgo Cluster and the need for caution when interpreting kinematic measurements from various dynamical tracers.

309.02D – Determination of Resonance Locations in Spiral Galaxies using Multi-band Photometry

Amber Sierra[1], Marc Seigar[1], Patrick M. Treuthardt[2], Ivanio Puerari[3]

1. University of Arkansas at Little Rock, Little Rock, AR, United States. 2. North Carolina Museum of Natural Sciences, Raleigh, NC, United States. 3. INAOEP, Puebla, Mexico.

We have selected a sub-sample of ground-based ugriz band images of face-on barred spiral galaxies from the EFIGI galaxy survey. We take Fourier transforms along radial cuts in all wavebands and compare the phase angles as a function of radius between them. The radius at which the phase angles cross indicates the location of the co-rotation radius. We compare this with previously determined locations of the co-rotation radii (where available) using various alternative methods.

309.03 – Kinematics of Andromeda's Stellar Disk

Claire Dorman[1], Puragra Guhathakurta[1]

1. UC Santa Cruz, Santa Cruz, CA, United States.

Contributing teams: PHAT collaboration, SPLASH collaboration

The Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo (SPLASH) survey has so far measured radial velocities of over 10,000 individual bright stars in the inner 20 kpc of the Andromeda galaxy with the Keck/DEIMOS multiobject spectrograph. The survey samples disk populations of a variety of ages: young, massive main sequence and supergiant stars, intermediate-age AGB objects, and older red giant branch stars. Complementing this extensive dataset are velocity fields of the ionized gas from the same Keck/DEIMOS survey and neutral HI from the literature. We compare the kinematical structure of the old stellar, young stellar, neutral gas and ionized gas disks, measuring the relative velocity dispersions and rotation velocity lags. We discuss the evidence for thin, thick and kicked-up stellar disk components.

309.04 – The Inner Mass Structure of Observed Galaxies

Rachel Kuzio de Naray[1], Stacy S. McGaugh[2]

1. Georgia State University, Atlanta, GA, United States. 2. Case Western Reserve University, Cleveland, OH, United States.

We investigate the inner mass structure of a sample of dispersion-supported and rotation-supported galaxies that includes dwarf spheroidals, disks, and massive ellipticals. We find that the total (baryonic+dark matter) dynamical mass inside of 500pc is nearly independent of the overall structure of the galaxy: over ~ 9 orders of magnitude in baryonic mass and ~ 3 in length scale, the total dynamical mass inside 500pc increases less than 1.5 orders of magnitude. We use these data to evaluate recent galaxy simulations and find that baryonic feedback models are successful in matching the observed dynamical mass enclosed within 500pc if the total stellar mass of the simulated galaxy is less than 10^{9} $M_{\odot}$. More massive simulations, however, have significantly more mass in the inner 500pc than observed disk galaxies. At the high mass end of the galaxy spectrum, current feedback models face the challenge that some galaxies are too massive to change

with straightforward feedback.

309.05 – Supermassive Black Holes in Low-Mass Bulges, Pseudobulges, and Composite Bulges

Peter Erwin[1,2], Roberto Saglia[1,2], Jens Thomas[1,2], Maximilian Fabricius[1,2], Stephanie Rusli[1,2], Nina Nowak[3], Michael Opitsch[1,2], Ralf Bender[1,2], Michael J. Williams[1,2], Ximena Mazzalay[1,2]
1. MPE, Garching b. Muenchen, Germany. 2. Universitaets Sternwarte Muenchen, Munich, Germany. 3. MPP, Munich, Germany.

We report direct dynamical measurements of supermassive black hole masses in nearby S0 and spiral galaxies, including systems with classical bulges, pseudobulges, and composite systems which host both disky pseudobulges and classical bulges. The primary data used are stellar kinematics obtained with the SINFONI near-IR IFU on the VLT in adaptive-optics mode (using both natural and laser guide stars), with resolutions down to 0.08 arcsec FWHM. We treat the galaxies as multi-component systems, using careful decompositions to separate out stellar components (e.g., nuclear star clusters, bulges, pseudobulges, disks) which can take on different M/L ratios in the modeling process. Using Schwarzschild modeling, we obtain central black hole masses for nine galaxies and upper limits for two more. We will comment on possible relations between the black hole masses and the characteristics of the host galaxies, including bulge versus pseudobulge components for composite-bulge galaxies.

309.06 – Modeling and Fitting Tidal Stellar Streams

Mark A. Fardal[1], Shuiyao Huang[1], Martin D. Weinberg[1]
1. University of Massachusetts, Amherst, MA, United States.
Contributing teams: PAndAS, SPLASH

I discuss several results on tidal streams from star clusters and satellite galaxies orbiting more massive host galaxies. First, I discuss qualitatively the deviation of the stream from the orbital path and the formation of substructure within the stream; both effects have several distinct regimes. Next, I present an method of fitting models of tidal streams to observations which is more accurate than simple orbital fits and less time-consuming than full N-body simulations. This method allows for a thorough exploration of parameter space. Finally, I present model fits and parameter constraints using a metal-poor tidal stream in M31.

309.07 – Powerful Molecular Outflows in Nearby ULIRGs and Quasars

Sylvain Veilleux[1], Marcio Melendez[1]
1. Univ. of Maryland, College Park, MD, United States.
Contributing teams: The SHINING Team

Our survey of nearby ULIRGs and quasars with Herschel-PACS (SHINING and its OT1 and OT2 extensions) has revealed powerful molecular outflows in a number of systems. I will summarize the properties of these outflows and compare them with what we know at other wavelengths. I will put these results in the broader context of quasar feedback and galaxy evolution.

309.08 – Suppression of star formation in the galaxy NGC 253 by a starburst-driven molecular wind

Steven R. Warren[1], Alberto D. Bolatto[1], Adam K. Leroy[2], Fabian Walter[3], Sylvain Veilleux[1], Eve C. Ostriker[4], Juergen Ott[5], Martin Zwaan[6], David B. Fisher[1], Axel Weiss[7], Erik Rosolowsky[8], Jacqueline Hodge[3]
1. University of Maryland, College Park, MD, United States. 2. NRAO, Charlottesville, VA, United States. 3. Max-Planck Institut für Astronomie, Heidelberg, Germany. 4. Princeton University, Princeton, NJ, United States. 5. NRAO, Socorro, NM, United States. 6. ESO, Garching, Germany. 7. Max-Planck Institut für Radioastronomie, Bonn, Germany. 8. University of British Columbia, Kelowna, BC, Canada.

We present Atacama Large (Sub)Millimeter Array (ALMA) CO (J=1-0) observations of the nearby, nuclear starburst galaxy NGC 253. NGC 253 is host to a "superwind" emanating from the central ~200 pc. Galaxy superwinds are thought to help shape the galactic mass function, play a critical role in galaxy evolution, and pollute the intergalactic medium with heavy metals. Detailed studies of nearby systems frequently focus on the warm or hot phases of the wind, visible in X-ray or Halpha emission. However, most of the mass in the outflowing material is thought to be in the form of neutral atomic and molecular gas. We use the observed CO luminosities and velocities to estimate the mass, mass loss rate, and energetics of the molecular

wind. We compute an outflow mass of $M\_mol \sim 6.6 \times 10^6$ Msun. The observed projected velocities of the CO filaments range from ~30-60 km s^-1 resulting in a mass loss rate of ~9 Msun yr^-1. The nuclear region of NGC 253 has a star formation rate of ~3 Msun yr^-1 resulting in a mass loading parameter n~1-3. It is not immediately clear if the outflowing gas will escape the halo or eventually rain back onto the disk. What is clear is that NGC 253 will exhaust its nuclear star forming gas in ~60-120 Myr at its current mass loss rate, cementing the superwind as an important contributor in the evolution of NGC 253.

310 – Galaxy Evolution at z~2
Oral Session – Potomac Ballroom A – 08 Jan 2014 10:00 am to 11:30 am

310.01 – Ultra-Faint Ultraviolet Galaxies at the Epoch of Peak Star Formation 1 < z < 3

Anahita Alavi[1], Brian D. Siana[1], Johan Richard[2], Daniel Stark[3], Claudia Scarlata[4], Harry I. Teplitz[5], William R. Freeman[1], Alberto Dominguez[1], Marc Rafelski[5], Brant E. Robertson[3], Vandana Desai[6]
1. University of California Riverside, Riverside, CA, United States. 2. Centre de Recherche Astronomique de Lyon, Saint-Genis-Laval, France. 3. University of Arizona, Tucson, AZ, United States. 4. University of Minnesota, Minneapolis, MN, United States. 5. California Institute of Technology, Pasadena, CA, United States. 6. Jet Propulsion Laboratory, Pasadena, CA, United States.

Ultra-faint star-forming galaxies produce a significant fraction of global star formation rate density at high redshifts. The magnification provided by strong gravitational lensing from massive clusters enables us to detect the faint background galaxies that are beyond our current detection limits. Using the massive lensing cluster Abell 1689 along with deep HST/WFC3 ultraviolet imaging (30 orbits in the F275W filter), we find that the UV luminosity function is steep down to very faint magnitudes (M_{UV} = -13 AB mag) and shows no turnover. Our new HST program images Abell 1689 for 10 and 14 orbits in F225W and F336W bands, respectively. We again use the Lyman break technique to select star-forming galaxies as F225W and F336W "dropouts" at z=1.5 and z=2.7, respectively. Finally, we end up with a large sample of ultra-faint star-forming galaxies at the peak epoch of star formation, 1 < z < 3. We study the evolution of the faint-end slope of the UV luminosity function as well as a variety of properties of faint star-forming galaxies in this sample. We also measure the Lyman continuum escape fraction in these feeble sources, as they play an important role in making up the ionizing background radiation at both intermediate redshifts (1<z<3) and the epoch of reionization (z>6).

310.02 – Physical properties of dwarf galaxies at z~2 from bursty star formation rate histories.

Alberto Dominguez[1], Brian D. Siana[1]
1. University of California, Riverside, CA, United States.

Recently, the magnification from gravitational lensing has allowed the discovery of a large population of low mass galaxies at z~2 behind the cluster Abell 1689. Such low mass galaxies are thought to have complicated star formation histories (SFHs) with frequent bursts of star formation and subsequent quenching. These bursty SFRHs are used to answer several problems regarding physical properties of dwarf galaxies at low redshift. SFHs from hydro-dynamical simulations are used to better determine the stellar masses and star formation rates of these galaxies. In this talk, the possibility of determining the SFHs of dwarf galaxies and their effect on the so-called main sequence of star formation is investigated. We focus on studying the scatter of the main sequence at these low masses and conclude that indicators sensitive to short timescales (of the order of a few Myr) such as Halpha are essential for their understanding. A simple observational test of burstiness is proposed by measuring the ratio of UV and Halpha luminosities, given that a significant fraction of UV-selected galaxies will be exceedingly faint in Halpha luminosity.

310.03 – A VIRUS-P Survey of Galaxy Clusters to Find Faint Lyα-emitting Galaxies

Emily McLinden[1], Steven L. Finkelstein[2], Brian D. Siana[3], Anahita Alavi[3]
1. UT Austin - McDonald Observatory, Austin, TX, United States. 2. University of Texas - Austin, Austin, TX, United States. 3. University of California Riverside, Riverside, CA, United States.

The VIRUS-P instrument on the 2.7m telescope at the McDonald Observatory was originally built as a prototype of the larger VIRUS instrument that will be used for HETDEX. We demonstrate that this multi-fiber, optical integral field unit spectrograph can be efficiently used to detect faint Lyα-emitting galaxies (LAEs) at intermediate redshift (z = 2-3) with the aid of gravitational lensing from galaxy clusters. The bulk z=2-3 LAEs to date have been discovered with narrowband imaging campaigns, which are highly efficient only at selecting L > L_star galaxies and only over a narrow redshift slice. By making use of gravitational lensing, however, we are able to observe intrinsically very faint galaxies that only appear to have brightnesses ? L_star. Gravitationally lensed faint LAEs, such as our sample from VIRUS-P, allow us to go fainter than existing narrowband surveys and therefore allow for better constraints at the faint end of the Lyα luminosity function at these intermediate redshifts.

310.04 – To Stack or Not To Stack: Spectral Energy Distribution Properties of Lyman Alpha Emitting Galaxies at z=2.1

Carlos J. Vargas[1, 2], Hannah Bish[1], Viviana Acquaviva[3], Eric J. Gawiser[1], Steven L. Finkelstein[4],

Robin Ciardullo[5]
1. Rutgers University, New Brunswick, NJ, United States. 2. New Mexico State University, Las Cruces, NM, United States. 3. New York City College of Technology, City University of New York, New York, NY, United States. 4. The University of Texas at Austin, Austin, TX, United States. 5. The Pennsylvania State University, University Park, PA, United States.
Contributing teams: The CANDELS Collaboration, The MUSYC Collaboration

We report the results of Vargas et al. (2013, ArXiV: 1309.6341). We use the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS) GOODS-S multi-wavelength catalog to identify counterparts for 20 Lyα Emitting (LAE) galaxies at z = 2.1. We build several types of stacked Spectral Energy Distributions (SEDs) of these objects. We combine photometry to form average and median flux-stacked SEDs, and postage stamp images to form average and median image-stacked SEDs. We also introduce scaled flux stacks that eliminate the influence of variation in overall brightness. We use the SED fitting code SpeedyMC to constrain the physical properties of individual objects and stacks. Our LAEs at z = 2.1 have stellar masses ranging from 2×10^7 Msun - 8×10^9 Msun (median = 3×10^8 Msun), ages ranging from 4 Myr to 500 Myr (median =100 Myr), and E(B-V) between 0.02 and 0.24 (median = 0.12). The SED parameters of the flux stacks match the average and median values of the individual objects, with the flux-scaled median SED performing best with reduced uncertainties. Median image-stacked SEDs provide a poor representation of the median individual object, and none of the stacking methods captures the large dispersion of LAE properties.

310.05 – A multi-wavelength imaging study of a large sample of galaxies at z?2: Implications for star formation and dust properties at high redshift

Irene Shivaei[1], Naveen Reddy[1]
1. Univ of CA, Riverside, Riverside, CA, United States.

From a unique sample of 262 UV-selected galaxies with spectroscopic redshifts at z?2 and rest-UV through Spitzer/IRAC near-IR photometry, we investigate their star-formation rates and dust attenuation based on multiple diagnostics. The sample includes galaxies at redshifts 2.08≤z≤2.51, where H-alpha falls in the K-band, and where the H-alpha flux can be estimated by comparing the K-band photometry to stellar population model fits to the UV- to near-IR photometry. This technique has the advantage of being immune to uncertain corrections for slit loss that can affect spectroscopic measurements of H-alpha. Comparing the H-alpha SFRs with those from the UV shows a general agreement between the two tracers if we assume that the nebular lines are attenuated by the same amount as the stellar continuum. We use the H-alpha, UV, and Spitzer/MIPS 24 micron data (where available) to examine the bolometric SFRs and recipes for dust corrections at high redshift.

310.06D – The impact of stellar radiation on the formation of dwarf galaxies

Sebastian Trujillo-Gomez[1], Anatoly A. Klypin[1], Pedro Colín[2], Daniel Ceverino[4], Kenza S. Arraki[1], Joel R. Primack[3]
1. Astronomy Department, New Mexico State University, Las Cruces, NM, United States. 2. Centro de Radioastronomia y Astrofísica, Universidad Nacional Autónoma de México, Morelia, Michoacán, Mexico. 3. Department of Physics, University of California at Santa Cruz, Santa Cruz, CA, United States. 4. Departamento de Física Teórica, Universidad Autónoma de Madrid, Madrid, Madrid, Spain.

We investigate the process of stellar mass assembly in dwarf galaxies, focusing on the effects of radiation from young star clusters on the star formation efficiency and the star formation histories of galaxies simulated to the present day. We incorporate a model of stellar feedback based on observations of star forming regions. The model includes radiation pressure from massive stars, as well supernova explosions and stellar winds. We find that radiation has a strong effect on the star formation process in dwarfs, especially at high redshift. In a low-mass halo, feedback efficiently suppresses star formation by dispersing and heating high density gas, mostly in the central regions, completely suppressing the formation of a concentrated stellar component. The star formation histories of the simulated dwarfs are consistent with the observation that the the bulk of the stellar mass assembly of low mass galaxies takes place in the last half of cosmic history, in sharp contrast with the hierarchical assembly of their dark matter halos. We also find that radiation feedback does not reduce the total baryon fraction of low mass dark matter halos. Instead, its main role is to keep gas in a warm, low density phase where it does not form stars. The fraction of cold baryons within the simulated galaxies is near cosmological, in excellent agreement with observational inferences. In addition, radiation pressure reduces the central dark matter density of a dwarf galaxy with a stellar mass ~10^8 M_sun, in accord with observations.

310.07 – The insignificance of major mergers in the early Universe

Sugata Kaviraj[1,2], Seth H. Cohen[3], Rogier A. Windhorst[3], Joseph I. Silk[2], Richard S. Ellis[4], Avishai Dekel[5]

1. University of Hertfordshire, Hatfield, Hertfordshire, United Kingdom. 2. University of Oxford, Oxford, Oxfordshire, United Kingdom. 3. Arizona State University, Phoenix, AZ, United States. 4. Caltech, Pasadena, CA, United States. 5. Hebrew University of Jerusalem, Jerusalem, Jerusalem, Israel.

Contributing teams: WFC3 Science Organising Committee

We present observational evidence that argues against major mergers having a prominent role in driving star formation and creating spheroids in the early Universe. Employing visually-classified morphologies from rest-frame V-band HST imaging (via the WFC3 ERS programme), we show that only ~15% of the cosmic star formation can be attributed to the major-merger process at z~2. Furthermore, at least 50% of blue (i.e. star forming) spheroids at 1<z<3 do not show tidal features that are expected (based on hydro-simulations) from major mergers at these epochs. This indicates that the formation of a significant fraction of primordial spheroids may be unrelated to the major-merger process. Taken together, our results point processes other than major mergers (e.g. minor mergers or direct accretion via cold streams), as the primary drivers of star formation and spheroid production in the early Universe.

311 – Gamma Ray Bursts: Multi-wavelength and Afterglow

Oral Session – Maryland Ballroom D – 08 Jan 2014 10:00 am to 11:30 am

311.01D – Unveiling the Progenitors of Short-duration Gamma-ray Bursts

Wen-fai Fong[1]
1. Havard Center for Astrophysics, Cambridge, MA, United States.

While long-duration gamma-ray bursts (GRBs, duration > 2 sec) are linked to the catastrophic death of massive stars, the progenitors of short-duration GRBs (duration < 2 sec) are less certain. From the past few decades of theoretical predictions, the most favored progenitor is the coalescence of two compact objects, either involving two neutron stars or a neutron star and a black hole. Such systems are the premier candidates for gravitational wave signals, which is one of the most anticipated discoveries of the century. Thus, understanding the progenitors and fundamental explosion properties of short GRBs is critical to inform our understanding of the electromagnetic counterparts to gravitational waves. In this talk, I present several lines of observational evidence from their host populations and afterglows linking short GRBs to a compact object binary merger origin. I also present the latest constraints on the opening angle distribution, which directly affects the true energy scale and event rate. Finally, I investigate the next steps for observations of short GRBs in the upcoming era of gravitational wave astronomy.

311.02 – Radio Observations Of GRB 100418a: Test Of An Energy Injection Model Explaining Long-Lasting GRB Afterglows

Aquib Moin[1,2], Poonam Chandra[5], James Miller-Jones[3], Steven Tingay[3], Gregory B. Taylor[7,4], Dale A. Frail[4], Zhongxiang Wang[2], Cormac Reynolds[3], Chris Phillips[6]
1. New York University Abu Dhabi, Abu Dhabi, Abu Dhabi, United Arab Emirates. 2. Shanghai Astronomical Observatory, Shanghai, Shanghai, China. 3. ICRAR/Curtin University, Perth, WA, Australia. 4. NRAO, Socorro, NM, United States. 5. NCRA TIFR, Pune, Maharashtra, India. 6. ATNF CASS, Sydney, NSW, Australia. 7. University of New Mexico, Albuquerque, NM, United States.

I will highlight the results of our radio observational campaign on GRB 100418a, for which the Australia Telescope Compact Array (ATCA), Very Large Array (VLA) and the Very Long Baseline Array (VLBA) were used. GRB 100418a was a peculiar GRB with unusual X-ray and optical afterglow profiles featuring a plateau phase with a very shallow rise. This observed plateau phase was believed to be due to a continued energy injection mechanism, which powered the forward shock, giving rise to an unusual and long-lasting afterglow. The radio afterglow of GRB 100418a was detectable several weeks after the prompt emission. We conducted long-term monitoring observations of the afterglow and attempted to test the energy injection model advocating that the continuous energy injection is due to shells of material moving at a wide range of Lorentz factors. We obtained an upper limit of ? < 7 for the expansion rate of the GRB 100418a radio afterglow, indicating that the range-of-Lorentz factor model could only be applicable for relatively slow moving ejecta. A preferred explanation could be that continued activity of the central engine may have powered the long-lasting afterglow.

311.03 – Limits on GRB Prompt Radio Emission Using the LWA1

Kenneth S. Obenberger[1], Jacob M. Hartman[2], Gregory B. Taylor[1], Joseph Craig[1], Jayce Dowell[1], Joseph F. Helmboldt[3], Patricia A. Henning[1], Frank Schinzel[1], Thomas L. Wilson[3]
1. University of New Mexico, Albuquerque, NM, United States. 2. NASA Jet Propulsion Laboratory, Pasadena, CA, United States. 3. US Naval Research Laboratory, Washington, DC, United States.

As a backend to the first station of the Long Wavelength Array (LWA1) the Prototype All Sky Imager (PASI) has been imaging the sky > -26° declination during 34 GRBs (Gamma Ray Bursts) between January 2012 and May 2013. Using this data we were able to put limits on prompt low frequency emission from GRBs. While our limits depend on the zenith angle of the observed GRB, we estimate a 1? RMS sensitivity of 68, 65 and 70 Jy for 5 second integrations at 37.9, 52.0, and 74.0 MHz at zenith. These limits are relevant for pulses ? 5 s and are limited by dispersion smearing. For pulses of length 5 s we are limited to dispersion measures (DMs) $\leq$ 220, 570, and 1,600 pc cm^3 for the frequencies above. For pulses lasting longer than 5s, the DM limits increase linearly with the duration of the pulse. We also report two interesting transients, which are, as of yet, of unknown origin, and are not coincident with any known GRBs. For general transients, we give rate density limits of $\leq$ 7.5 $\times$ 10^3, 2.9 $\times$ 10^2, and 1.4 $\times$ 10^2 yr^1 deg^2 with pulse energy densities > 1.3 $\times$ 10^{22}, 1.1 $\times$ 10^{22}, and 1.4 $\times$ 10^{22} J m^2 Hz^1 and pulse widths of 5 s at the frequencies given above.

311.04 – Shocked by the Very Bright Radio Flare and Afterglow of GRB 130427A

Alexander J. van der Horst[1]

1. Astronomical Institute, University of Amsterdam, Amsterdam, Netherlands.

Gamma-ray burst (GRB) 130427A was extremely bright across the electromagnetic spectrum, with emission spanning 16 orders of magnitude in observing frequency, from almost 100 GeV gamma-rays down to the GHz radio regime. While the intrinsic luminosity of this GRB was not extreme compared to other GRBs, it displayed the largest measured fluence of the last three decades due to its proximity with a redshift of 0.34. One of the most notable characteristics of this GRB was its bright radio emission, in particular the radio flare which has been observed only a few times in other GRBs and is usually attributed to the reverse shock moving back into the GRB jet. Here we present radio observations with unprecedented temporal coverage at three observing frequencies obtained with the Westerbork Synthesis Radio Telescope (WSRT) and the Arcminute Microkelvin Imager (AMI). AMI had the earliest radio detection at 8 hours after the initial flash of gamma-rays, catching the radio flare on the rise. The 12-hour WSRT observations in the first few days enabled a detailed study of the short time-scale behavior at radio wavelengths. Besides our observations of the radio flare and afterglow up to three months after the gamma-ray trigger, we present our results for modeling the radio light curves together with the broadband data set in various other wavelength regimes, enabling us to determine physical parameters of both the reverse and forward shock of this enigmatic GRB.

311.05 – An Account of the GRB afterglow steep-decline-and-plateau phase

Demosthenes Kazanas[1], Joseph Sultana[2], Apostolos Mastichiadis[3]
1. NASA's GSFC, Greenbelt, MD, United States. 2. University of Malta, Msida, Malta. 3. University of Athens, Athens, Greece.

We present a process that accounts for the steep-decline-and-plateau phase of the Swift-XRT light curves, vexing features of GRB phenomenology. This process is an integral part of the ``supercritical pile'' GRB model, proposed a few years ago to an account for the conversion of the GRB kinetic energy into radiation with a spectral peak at $E_{\rm pk} \sim m_ec^2$. We compute the evolution of the relativistic blast wave (RBW) Lorentz factor Γ to show that the radiation--reaction force due to the GRB emission can produce an abrupt, small ($\sim 25\%$) decrease in Γ at a radius which is smaller (depending on conditions) than the deceleration radius R_D. Because of this reduction, the kinematic criticality criterion of the ``supercritical pile'' is no longer fulfilled. Transfer of the proton energy into electrons ceases, and the GRB enters abruptly the afterglow phase at a luminosity smaller by $\sim m_p/m_e$ than that of the prompt emission. If the radius at which this slow-down occurs is significantly smaller than R_D, the RBW internal energy continues to drive the RBW expansion at a constant (new) Γ, and its X-ray luminosity remains constant until R_D is reached, at point it resumes its more conventional decay, thereby completing the``unexpected'' XRT light curve phase. If this transition occurs at $R \simeq R_D$, the steep decline is followed by a flux decrease instead of a ``plateau'', consistent with the conventional afterglow declines. Besides providing an account of these peculiarities, the model suggests that the afterglow phase may in fact begin before the RBW reaches $R \simeq R_D$, thus introducing novel insights into the GRB phenomenology.

311.07 – Fast Radio Bursts: Further Detections and Multi-wavelength Searches

Sarah Spolaor[1,2]
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Contributing teams: High Time Resolution Universe Survey, V-Fastr Collaboration

Short, dispersed radio bursts from extragalactic sources have been the ultimate target of a number of surveys over the last ~1.5 decades. The regular detection and classification of such events could open new avenues through the cosmology of baryonic intergalactic media, relativistic astrophysics, and gravitational wave event markers. The High Time Resolution Universe (HTRU) Survey, which was designed specifically to find highly dispersed millisecond pulsars and extragalactic radio bursts, revealed this year the most compelling case to date for a genuine population of extragalactic radio bursts. I will present an update of discoveries and follow-up efforts within the HTRU Survey since the publication of Thornton et al., and will note efforts with NRAO interferometers to simultaneously detect and localize FRBs in the future.

312 – Interstellar Medium & Dust III

Oral Session – National Harbor 13 – 08 Jan 2014 10:00 am to 11:30 am

312.01 – The WISE Catalog of Galactic HII Regions Website

Loren D. Anderson[1]
1. West Virginia University, Morgantown, WV, United States.

The WISE Catalog of Galactic HII Regions has catalogued over 8000 objects, including all approximately 2000 known Galactic HII regions and over 6000 HII region candidates. As part of this effort, we created a flexible and interactive website to showcase the catalog contents and to allow quick access to the data. This website uses Google Fusion Tables and the Google Maps interface. We will detail the steps used to create the site, explain the user interface, and describe how other researchers can easily build off our experience to create similar sites of their own.

312.02D – Rotationally Excited H2 in the Magellanic Clouds

Rui Xue[1], Tony H. Wong[1], Daniel E. Welty[2]
1. University of Illinois, Urbana, IL, United States. 2. University of Chicago, Chicago, IL, United States.

We have performed a systematic analysis of excited-state (up to J=5) H2 Lyman-Werner absorption lines using archival spectra in the FUSE Magellanic Clouds Legacy Project. The H2 column densities at different ground state J-levels and the Doppler broadening parameter b are determined for both Magellanic and Galactic components along each line of sight. Combining the results with previously measured total gas column densities of HI and H2, we derive the H2 excitation temperature, volume density, and local UV field strength for the absorbing gas. The physical and chemical properties of the absorbers are compared with Galactic samples, and also used to test predictions from multiple-phase ISM equilibrium models. Finally, we compare the absorbing gas from the Magellanic Clouds with its larger-scale ISM environment as revealed in previous surveys of gas and dust emission, extending our results from the UV data measured along moderately reddened sight lines to more dense gas detected in emission.

312.03 – The Role of Stellar Feedback in the Dynamics of HII Regions

Laura A. Lopez[1]
1. MIT, Cambridge, MA, United States.

Stellar feedback is often cited as the biggest uncertainty in galaxy formation models today. This uncertainty stems from a dearth of observational constraints as well as the great dynamic range between the small scales (<1 pc) where the feedback occurs and the large scales of galaxies (>1 kpc) that are shaped by this feedback. To bridge this divide, in this paper we aim to assess observationally the role of stellar feedback at the intermediate scales of HII regions. In particular, we employ multiwavelength data to examine several stellar feedback mechanisms in a sample of 32 HII regions in the Large and Small Magellanic Clouds (LMC and SMC, respectively). Using optical, infrared, radio, and X-ray images, we measure the pressures exerted on the shells from the direct stellar radiation, the dust-processed radiation, the warm ionized gas, and the hot X-ray emitting gas. We find that the warm ionized gas dominates over the other terms in all of the sources, although two have comparable dust-processed radiation pressures to their warm gas pressures. The hot gas pressures are comparatively weak, while the direct radiation pressures are 1-2 orders of magnitude below the other terms. We discuss the implications of these results, particularly highlighting evidence for hot gas leakage from the HII shells and regarding the momentum deposition from the dust-processed radiation to the warm gas. Furthermore, we emphasize that similar observational work should be done on very young HII regions to test whether direct radiation pressure and hot gas can drive the dynamics at early times.

312.04 – The CO-to-H2 Conversion Factor and Dust-to-Gas Ratio on Kiloparsec Scales in Nearby Galaxies

Karin Sandstrom[1], Adam K. Leroy[2], Robert Kennicutt[3]
1. University of Arizona, Tucson, AZ, United States. 2. NRAO, Charlottesville, VA, United States. 3. Institute of Astronomy, University of Cambridge, Cambridge, United Kingdom.
Contributing teams: KINGFISH team, HERACLES team

Tracing molecular gas mass using the rotational transitions of the 12CO molecule is a key technique for studies of the interstellar medium and star formation at all redshifts. Because of this, understanding the variability of the CO-to-H2 conversion factor (alpha_CO) as a function of local environmental conditions is crucial. We present results of a recent study measuring alpha_CO and dust-to-gas ratio (DGR) resolved on ~kiloparsec scales in nearby galaxies. By resolving the galaxies using far-IR observations from the Herschel Key program KINGFISH to trace dust, the IRAM large program HERACLES to trace molecular gas and VLA survey THINGS to trace atomic gas, we can relate the variations in alpha_CO and DGR to galactic environment. We find that galaxies in our sample typically show a flat radial profile of alpha_CO with an average

value very similar to what is found in the Milky Way. This is not true in their centers, however, where alpha_CO can be much lower. Metallicity does not appear to be a major driver of alpha_CO variations in these galaxies. It is, however, well correlated with DGR as one would expect if an approximately constant fraction of heavy elements were tied up in dust grains. In the centers of galaxies, the low alpha_CO may be related to changes in molecular gas heating or dynamics and we discuss potential causes for the variations we observe. Finally, we discuss the implications of our alpha_CO measurements for understanding the star formation efficiency and molecular gas distributions in galaxies.

312.05 – Anomalous Microwave Emission in HII regions: is it really anomalous? The case of RCW 49

Roberta Paladini[1], Adriano Ingallinera[1], Claudia Agliozzo[1], Christopher Tibbs[1], Clive Dickinson[1], Corrado Trigiglio[1], Grazia Umana[1], Alberto Noriega-Crespo[1], Nicolas Flagey[1]
1. NHSC/Caltech, Pasadena, CA, United States.

The detection of an excess of emission at microwave frequencies with respect to the predicted free-free emission is reported for several Galactic HII regions. Here, we investigate the case of RCW 49, the brightest Galactic HII region of the Southern hemisphere, for which the Caltech Background Imager (CBI) tentatively (~ 3 sigma) detected Anomalous Microwave Emission at 31 GHz. Using the Australia Telescope Compact Array (ATCA), we carried out continuum multi-frequency observations (5 GHz, 19 GHz and 34 GHz) of an area of 7.8' X 5.6' centered on the CBI 31-GHz peak of emission, complemented by observations of the H109alpha hydrogen Radio Recombination Line of the same region. The analysis of the continuum and line data show that: 1) the microwave-IR correlation found by the Caltech Background Imager on scales of ~ 6' appears to persist on arcsec angular scales (0.4'' - 1'); 2) there is evidence of rising spectral indices between 1.4 and 5 GHz and these are compatible with the presence of strong stellar winds, possibly generated by the Westerlund 2 cluster; 3) the anomalous emission in RCW 49 cannot be attributed to inverted free-free associated with Ultra Compact HII regions. Finally, we propose that what is observed in RCW 49 might not be specific of this HII region only, and that the excess of microwave emission in this type of sources might not have an "anomalous" origin, but rather simply be ascribed to stellar winds and/or shocks phenomena.

312.06 – Diagnosing Pressure in Molecular Clouds through Observations and Simulations

Christopher Faesi[1], Stella Offner[2], Alyssa A. Goodman[1], Thomas Bisbas[3]
1. Harvard Univ., Cambridge, MA, United States. 2. Yale University, New Haven, CT, United States. 3. University College London, London, United Kingdom.

Pressure plays a key role in the dynamics of molecular clouds, the birthplaces of stars. Internally, pressure acts against gravity, resisting global collapse and helping explain the overall low star formation efficiencies observed. Externally, the pressure of the ambient lower-density interstellar medium (ISM), in which molecular clouds form, may help to promote cloud stability over timescales long enough for star formation to occur. This basic picture is complicated by several factors. For one, the internal structure of molecular clouds is extremely complex. Turbulent motions, which are supersonic on all but the smallest scales within clouds, promote support globally, but can also create shocks, leading to intricate substructure in a cloud's density and velocity fields. Furthermore, the boundary of a cloud (on which external pressure presumably acts) is difficult to concretely define, as there is in reality a relatively smooth transition from the more diffuse, warm, atomic ISM to the dense, cold, molecule-dominated cloud itself. Observational diagnostics of pressure are scarce, as they require simultaneous measurement of both gas motions and density. Moreover, assessing the role of pressure in detail within clouds is contingent on knowledge of the cloud's internal hierarchy. We present a new diagnostic probe of pressure as a function of scale within molecular clouds. We employ ^{13}CO molecular line data from the COMPLETE survey to decompose a molecular cloud into its hierarchical substructure through the use of dendrogram analysis. We take the "kinetic pressure" in the gas to be $P = ??\sigma_v^2$, where ? is the volume density derived from molecular line intensity and simple geometric assumptions, and $?_v$ is the velocity dispersion computed from spectral linewidths. Specifically, we calculate the kinetic pressure within and at the interface between each nested structure in the dendrogram. We compare observational results on the Perseus molecular cloud with analysis of radiative transfer-processed turbulent simulations to assess the ability of our diagnostic to measure the true pressure within star-forming gas.

312.07 – Modelling Photo Dissociation Region near Ultracompact H II region

D. Anish Roshi[1], S. Jeyakumar[2]
1. National Radio Astronomy Observatory, Charlottesville, VA, United States. 2. Departamento de Astronom{\'i}a, Universidad de Guanajuato, Guanajuato, CP 36000, Mexico.

We developed model to investigate Carbon Recombination Line (CRL) emission from the Photo Dissociation Region (PDR) surrounding the Ultra-Compact (UC) HII region. Our modelling shows that the inner regions (A_V ~ 1) of the CII layer in the PDR contribute significantly to the CRL emission. The dependence of line ratios of CRL emission with the density of the PDR

and the far ultra-violet (FUV) radiation incident on the region is explored over a large range of these parameters that are typical for the environments of UCHII regions. We find that by observing a suitable set of CRLs it is possible to constrain the density of the PDR. If the neutral density in the PDR is high (> 10^7 \cmthree) CRL emission is bright at high frequencies (> 20 GHz), and absorption lines from such regions can be detected at low frequencies (< 10 GHz). CRL emission at high frequencies from such PDRs is mostly spontaneous emission and hence can be used to measure the expansion of UCHII regions. We then applied our model to investigate CRLs observed toward the UCHII region W48A. We found that W48A is embedded in a molecular cloud of density of about 4 x 10^7 \cmthree.

312.08 – Sensitive Survey of Molecular lines in the Taurus Molecular Cloud in frequency 39 to 47 GHz

Glen Langston[1]

1. National Science Foundation, Washington, DC, United States.

We present a high velocity resolution (0.04 km/sec) molecular line survey of the Taurus Molecular Cloud in the frequency range 39 to 47 GHz. The observing method and data reduction process are described. We also describe the method of obtaining the calibrated, averaged spectral line data. The survey was made dividing the 39 to 47 GHz band into 43 different sub-bands, each covering 200 MHz of bandwidth. The goal of the survey was to observe each range for 1 hour. The RMS survey sensitivity (for 6kHz channels) was different for each frequency band, and ranged from 0.02 to 0.15 K for the different sub-bands. A large number of molecular lines are detected, most of which have previously been associated with previously discovered molecules. Other transitions remain unidentified. We present a summary of different processes methods to search for new molecular species.

313 – Large Scale Structure & Cosmic Distance I
Oral Session – National Harbor 4 – 08 Jan 2014 10:00 am to 11:30 am

313.01D – Observations give us CLUES to Cosmic Flows' origins

Jenny Sorce[1, 2], Helene Courtois[1, 5], Stefan Gottloeber[2], Yehuda Hoffman[3], Daniel Pomarede[4], R. B. Tully[5]
1. University of Lyon, CNRS/IN2P3, Nuclear Physics Institute, Villeurbanne, France. 2. Leibniz-Institut fur Astrophysik, Potsdam, Germany. 3. Racah Institute of Physics, Hebrew University, Jerusalem, Israel. 4. CEA/IRFU, Saclay, Gif-sur-Yvette, France. 5. Institute for Astronomy, University of Hawaii, Honolulu, HI, United States.
Contributing teams: Cosmic Flows, CLUES

In an era where the wealth of telescope-data and the development of computer superclusters keep increasing, the knowledge of Large Scale Structures' formation and evolution constitutes a tremendous challenge. Within this context the project Cosmic Flows has recently produced a catalog of peculiar velocities up to 150 Mpc. These velocities, obtained from direct distance measurements, are ideal markers of the underlying gravitational potential. They form a fantastic input to perform constrained simulations of the Local Universe within the CLUES project. A new method has recently been elaborated to achieve these simulations which prove to be excellent replicas of our neighborhood. The Wiener-Filter, the Reverse Zel'dovich Approximation and the Constrained Realization techniques are combined to build Initial Conditions. The resulting second generation of constrained simulations presents us the formidable history of the Great Attractor's and nearby supercluster's formation.

313.02 – Improving cosmic distance meaurements by reconstructing the WiggleZ Dark Energy Survey density field

Eyal Kazin[1], Chris Blake[1], Jun Koda[1], Nikhil Padmanabhan[2]
1. Swinburne University of Technology, Melbourne, VIC, Australia. 2. Yale, New Haven, CT, United States.

The reconstruction of the baryonic acoustic feature technique has recently been shown successful at improving the usage of galaxy maps to determine cosmic distances. We revisit the analysis of the large-scale two-point correlation function of the WiggleZ Dark Energy Survey galaxies, while applying reconstruction. We investigate three redshift bins between $0.2 < z < 1$ and find significant improvement in the detection of the baryonic acoustic feature and its usage as a standard ruler.

313.03D – Probing Galaxy Evolution and Cosmology using Cosmic Voids in SDSS-III

Qingqing Mao[1], Andreas A. Berlind[1], Robert Scherrer[1], Cameron McBride[2], Mark C. Neyrinck[3], Roman Scoccimarro[4], Jeremy Tinker[4]
1. Vanderbilt University, Nashville, TN, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. Johns Hopkins University, Baltimore, MD, United States. 4. New York University, New York, NY, United States.

We construct a comprehensive void catalog from SDSS-III DR10 using the ZOBOV void finding algorithm (Neyrinck 2008). We first study the general properties and the statistics of the voids, such as size and redshift distributions, and compare with predictions from cosmological simulations. We then identify galaxies living in cosmic voids and compare their properties to galaxies living in higher density environments, focusing on whether the relationship between stellar and halo mass is different in voids. Finally, we stack voids from the void catalog and measure the shapes of the stacked voids in order to construct an Alcock-Paczynski (AP) test and constrain cosmology. We discuss the capability of using this method to constrain cosmological parameters in future redshift surveys.

313.04D – Configuring the Cosmos: New Approaches to Modeling Nonlinear Structure Formation

Nuala McCullagh[1], Alexander S. Szalay[1], Mark C. Neyrinck[1], Donghui Jeong[1]
1. Johns Hopkins University, Baltimore, MD, United States.

A theoretical understanding of nonlinear structure formation is essential for extracting cosmological information from the large-scale structure in the Universe. I will present a new approach to perturbation theory in configuration space using the Zel'dovich Approximation. I will show that working in configuration space can simplify the higher-order corrections, and that the result can be straightforwardly extended to include redshift-space distortions. I also discuss how this model can be used

to understand the effects of local density transformations on the Baryon Acoustic Oscillation (BAO) peak in the correlation function. I show that the log transform gives a less-biased BAO peak location, which could lead to improved constraints on dark energy parameters.

314 – Scientific Opportunities with the James Webb Space Telescope

Special Session – Maryland Ballroom B – 08 Jan 2014 10:00 am to 11:30 am

The James Webb Space Telescope (JWST) will be a general purpose observatory that will provide research opportunities and support for thousands of astronomers. In this special session, speakers will describe JWST's potential for advancing a number of core scientific topics that are at the forefront of astrophysical research, with specific links to JWST's observing efficiency and multiple modes of imaging, spectroscopy, and coronography. Among the range of topics that will be covered in the session are Solar System science, planet formation and exoplanet characterization, star formation and the IMF, and galaxy formation and assembly.

314.01 – Supernova Forensics

Alicia M. Soderberg[1]
1. Harvard Smithsonian, CfA, Cambridge, MA, United States.

For decades, the study of stellar explosions -- supernovae -- have focused almost exclusively on the strong optical emission that dominates the bolometric luminosity in the days following the ultimate demise of the star. Yet many of the leading breakthroughs in our understanding of stellar death have been enabled by obtaining data at other wavelengths. For example, I have shown that 1% of all supernovae give rise to powerful relativistic jets, representing the biggest bangs in the Universe since the Big Bang. My recent serendipitous X-ray discovery of a supernova in the act of exploding ("in flagrante delicto") revealed a novel technique to discover new events and provide clues on the shock physics at the heart of the explosion. With the advent of sensitive new radio telescopes, my research group combines clues from across the electromagnetic spectrum (radio to gamma-ray), leading us to a holistic study of stellar death, the physics of the explosions, and their role in fertilizing the Universe with new elements, by providing the community with cosmic autopsy reports.

314.02 – Observing the solar system with JWST

Matthew S. Tiscareno[1], Heidi B. Hammel[2, 3], James Norwood[4], Stefanie N. Milam[5], Jonathan I. Lunine[1], Nancy J. Chanover[4], John A. Stansberry[6], Dean C. Hines[6], George Sonneborn[5], Michael E. Brown[7], Pierre Ferruit[8]
1. Cornell University, Ithaca, NY, United States. 2. Association of Universities for Research in Astronomy, Washington, DC, United States. 3. Space Science Institute, Boulder, CO, United States. 4. New Mexico State University, Las Cruces, NM, United States. 5. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 6. Space Telescope Science Institute, Baltimore, MD, United States. 7. California Institute of Technology, Pasadena, CA, United States. 8. European Space Agency, Noordwijk, Netherlands.

The solar system furnishes a suite of natural laboratories for studying topics ranging from comparative climatology to astrophysical disks. Furthermore, the solar system is our only source of ground truth for the increasingly diverse array of known exoplanets. The James Webb Space Telescope (JWST) will be capable of observing objects in the solar system with unprecedented detail and sensitivity. We will highlight several case studies for solar system observations with JWST, extracted from a white paper in preparation; the list of applications discussed here is far from comprehensive. The upcoming white paper updates and supersedes the solar system white paper published by the JWST Project in 2010 (Lunine et al., 2010).

314.03 – Directly Measuring the Low Mass IMF Outside the Milky Way with JWST

Marla C. Geha[1]
1. Yale University, New Haven, CT, United States.

The stellar initial mass function (IMF) parameterizes the relative number of stars formed in a single age population as a function of stellar mass. The IMF is fundamental to all calculations of star formation rates and galaxy stellar masses. Recent indirect estimates of the IMF, based on integrated galaxy light, suggest that the low mass IMF is not 'universal' and instead depends on galaxy properties. The majority of direct IMF studies, via counting stars, are limited to the nearby Galactic field and star clusters, which do not reflect the wide range of environments over which the IMF is routinely applied. We have recently demonstrated via optical HST/ACS photometry that the Milky Way ultra-faint dwarf galaxies have shallower IMF slopes as compared to the Milky Way over the mass range 0.5 - 0.75 M_sun. Infrared imaging is far more efficient in detecting a given low mass star, requiring a factor two less observing time as compared to the optical. However, even deep HST infrared imaging can measure the low mass IMF for only the innermost dwarf galaxies around the Milky Way. JWST provides a unique opportunity to probe the low mass IMF down to 0.3 Msun for all Milky Way dwarf galaxies and down to the hydrogen burning limit for the nearest dwarfs. JWST offers the promise of unambiguously measuring the functional form and slope of the low mass IMF in significantly different environments than the Milky Way and will directly test theories of low mass star formation.

314.04 – Insights into planetary systems through JWST imaging of debris disks

Mark Wyatt[1]

1. Institute of Astronomy, Cambridge, United Kingdom.

Analogy with the Solar System's asteroid and Kuiper belts illustrates how debris disks are an integral part of a planetary system. Studying the structure of extrasolar debris disks provides invaluable information on the dynamics of the planetary system in which they reside, and gives vital clues to the system's formation mechanism and subsequent evolution. For example, gaps in the dust distribution may indicate locations where planetesimal orbits are dynamically unstable due to the presence of nearby planets, and asymmetries in the dust distribution can indicate more complex dynamical effects from resonant and secular interactions with planets. Thus high resolution imaging studies are essential to our understanding of debris disks. Surveys with far-IR and sub-mm instruments have provided us with large numbers of debris disk candidates around nearby stars, and even low resolution images of several of these. However, searches for asymmetries in the disk structures, and exploring the possibility that the systems host multiple dust belts, requires even higher resolution; mid-IR wavelengths are also vital for probing the inner 10s of AU where planets may reside, but these are hard to access from the ground. JWST promises to revolutionize the field of debris disk imaging because its sensitivity and resolution means that it would be possible to obtain images of almost all debris disks known around A-type stars, and a large fraction of those around Sun-like stars. It will also be possible to search for mid-temperature dust belts, and to directly search for any perturbing planets, thus constraining any dynamical interaction much further.

314.05 – JWST Exoplanet Characterization: Big Opportunities for Small Planets Around Small Stars

John A. Johnson[1]

1. Harvard, Cambridge, MA, United States.

The NASA Kepler Mission has revealed the startling fact that there exist at least 1.5 planets per M dwarf throughout the Galaxy. The vast majority of these planets have radii comparable to the Earth and orbital periods less than 20 days. As a result, the next generation of transit surveys, TESS in particular, will discover a large sample of small planets orbiting nearby red dwarfs. These host stars, while faint in optical bands will be bright in the NIR and the small radii of the stars will enable opportunities to study the internal structures and atmospheric compositions of terrestrial planets. I will provide an overview of the types of targets that will likely be available for study by the time of JWST's launch and take a look ahead at the exoplanet characterization science opportunities will be available with the JWST instrument suite.

315 – Stars
Oral Session – Maryland 2 – 08 Jan 2014 10:00 am to 11:30 am

315.01 – Plans for Unprecedented Imaging of Stellar Surfaces with the NPOI

Anders M. Jorgensen[1], Henrique R. Schmitt[2], David Mozurkewich[3], Gerard van Belle[4], Donald J. Hutter[5], J. T. Armstrong[2], Ellyn K. Baines[2]

1. New Mexico Tech, Socorro, NM, United States. 2. Naval Research Laboratory, Washington, DC, United States. 3. Seabrook Engineering, Seabrook, MD, United States. 4. Lowell Observatory, Flagstaff, AZ, United States. 5. Naval Observatory Flagstaff Station, Flagstaff, AZ, United States.

This team was recently funded by the NSF for a project to modify the Navy Precision Optical Interferometer (NPOI) to be capable of unprecedented imaging of stellar surface features. The fidelity and resolution of the images are expected to exceed previous interferometric images. The project combines several existing advances and infrastructure at NPOI with modest enhancements. For optimal imaging there are several requirements that should be fulfilled. The observatory should be capable of measuring visibilities on a wide range of baseline lengths and orientations, providing complete UV coverage in a short period of time. It should measure visibility amplitudes with good SNR on all baselines as critical imaging information is often contained in low-amplitude visibilities. It should measure the visibility phase on all baselines. The technologies which can achieve this are the NPOI Y-shaped array with (nearly) equal spacing between telescopes and an ability for rapid configuration. Placing 6-telescopes in a row makes it possible to measure visibilities into the 4th lobe of the visibility function, and coherent integration techniques can be used to obtain good SNR on very small visibilities. Coherently integrated visibilities can be used for imaging with standard radio imaging packages such as AIPS. The commissioning of one additional station, the use of new hardware installed, and software enhancements can make this a reality. In this presentation we will give an overview of the project and its current status.

315.02D – Empirically Interrelating Stellar Magnetic Activity, Photometric Variability and Radial Velocity "Jitter" to Enhance Planet Discovery

Fabienne A. Bastien[1]

1. Vanderbilt University, Madison, TN, United States.

The magnetic activity of Sun-like stars, which can manifest as short time scale photometric and radial velocity (RV) variability, adds to the difficulty of detecting planets, particularly those in the Earth mass range: RV jitter can wash out the very small RV signal of such planets, and photometric "noise" caused by stellar activity can similarly preclude the detection of the tiny transit signature that a planet like ours would produce. Hence, in order to successfully detect Earth-like planets, via either the transit or RV method, the exoplanet community needs a way to characterize the photometric and RV stability of a star in advance. Many studies have examined pair-wise relationships between the magnetic activity, photometric variability and RV jitter of stars. We expand upon this work by using as our foundation the high quality photometric data from NASA's Kepler mission, supplemented by archival Keck RV measurements and our own Ca II H&K magnetic activity measurements, aiming to empirically interrelate all three quantities for both dwarf and evolved Sun-like stars. We find that some of the low level photometric variability correlates poorly with magnetic activity and instead traces granulation, yielding a simple tool to measure surface gravity with a precision of 0.1 dex. We tie the RV jitter of magnetically inactive stars (stars with observed RV jitter ranging from ~3m/s to 135.5m/s but with photometric variations of less than 3 mmag) to the Fourier complexity of the light curve, finding that higher frequency photometric variations drive the RV jitter. Finally, we present initial comparisons between magnetic activity, as traced by Ca II H&K measurements, and other measures of photometric variability, as well as ongoing and future applications of our work.

315.03 – Tracing Detailed Starspot Evolution with Kepler

James R. Davenport[1], Leslie Hebb[2], Suzanne L. Hawley[1]
1. University of Washington, Seattle, WA, United States. 2. Hobart and William Smith Colleges, Geneva, NY, United States.

Modeling sinusoidal flux variations in high precision photometry due to starspots, and their evolution over time, reveals critical information about the strength and nature of stellar magnetic fields. Photometry from the Kepler mission has discovered the presence of cool starspots on the surfaces of thousands of main sequence stars. Here we show preliminary results from our campaign to model the detailed time evolution of starspots on four stars. The rapidly rotating M4 star, GJ 1243, exhibits a remarkably stable polar starspot spanning three years of observation. A secondary polar spot is also seen, with an evolution timescale of hundreds of days. Three G/K stars with a wide range of rotation periods have also been studied, KOI-63, Kepler 17, and HAT-P-11. These systems all have planetary transits in their light curves, which we exploit to break degeneracies between spot surface coverage area and spot latitude. These transits can also probe smaller-scale starspot features on the stellar surface along a fixed latitude. By modeling the in- and out-of-eclipse light curves (see corresponding poster by L. Hebb) we are able to trace the detailed starspot evolution for several years in each system. This will help to constrain key physical parameters, such as mean rotation period, differential rotation, and diffusion timescales.

315.04 – ASASSN-13bc: A Dramatic Flare on an Ultracool Dwarf

Sarah J. Schmidt[1], Jose Prieto[2], Krzysztof Z. Stanek[1], Benjamin Shappee[1]
1. Ohio State University, Columbus, OH, United States. 2. Princeton University, Princeton, NJ, United States.

We present follow-up data on the newly identified M8 dwarf SDSS J022116.84+19402.4 (hereafter SDSS0221), first detected by the All-Sky Automated Survey for Supernovae (ASAS-SN) during a ?V~9 magnitude flare. SD0221 is spectroscopically confirmed as an M8 dwarf at both optical and infrared wavelengths, but shows no low gravity features indicating it is a young brown dwarf rather than a star. When modeled as classical flare, the light-curve is consistent with a total flare energy $E\_U = 10^{31}$ erg, indicating that it is less energetic than the largest flares observed on flaring mid-M dwarfs. When scaled to include a rough estimate of V-band emission line contribution, we estimate a blackbody filling factor of 10% to 34% during the flare peak and 0.8% to 1.5% during the flare decay phase, indicating that the flares cover a physically larger area than those on mid-M dwarfs.

315.05 – The intriguing X-ray variability of HD 150136

Jean-Christophe Leyder[1], Andrew M. Pollock[1]
1. European Space Astronomy Center, European Space Agency, Villanueva de la Cañada, Madrid, Spain.

HD 150136 is a multiple system harboring the nearest O3-type star. Its lightcurve indicates clear X-ray variability, whose origin is most likely due to a collision between the stellar winds. We recently obtained the first Chandra observation of HD 150136 covering an entire orbital period. Our goal is to definitively identify the cause of the X-ray variability. In addition, we plan to use the eclipses to obtain a direct measurement of the radius of an O3 star for the very first time. We will present the first results of our detailed X-ray study of HD150136.

315.06 – Innocent Bystanders and Smoking Guns: Dwarf Carbon Stars

Paul J. Green[1]
1. Harvard-Smithsonian CfA, Cambridge, MA, United States.

As far as we know, most carbon throughout the Universe is created and dispersed by AGB stars. So it was at first surprising to find that the carbon stars most prevalent in the Galaxy are in fact dwarfs. We suspect that dC stars are most likely innocent bystanders in post-mass transfer binaries, and may be predominantly metal-poor. Among 1200 C stars found in the SDSS (Green 2013), we confirm 724 dCs, of which a dozen are DA/dC stars in composite spectrum binaries, quadrupling the total sample of these "smoking guns" for AGB binary mass transfer. The dCs likely span absolute magnitudes M_i from about 6.5 to 10.5. G-type dC stars with weak CN and relatively blue colors are probably the most massive dCs still cool enough to show C_2 bands. Eleven very red C stars with strong red CN bands appear to be N-type AGB stars at large Galactocentric distances, one likely a new discovery in the dIrr galaxy Leo~A. Two such stars within 30arcmin of each other may trace a previously unidentified dwarf galaxy or tidal stream at ~40 kpc. We describe follow-up projects to study the spatial, kinematic, and binary properties of these C-enriched dwarfs.

315.07 – 3D Model Atmospheres of White Dwarfs

Pier-Emmanuel Tremblay[1], Hans-Günter Ludwig[2], Matthias Steffen[3], Bernd Freytag[4]

1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Zentrum für Astronomie der Universität Heidelberg, Heidelberg, Germany. 3. Leibniz Institute for Astrophysics Potsdam, Potsdam, Germany. 4. Centre de Recherche Astronomique de Lyon - Ecole Normale Supérieure, Lyon, France.

We present the first grid of 3D model atmospheres for hydrogen-atmosphere (DA) white dwarfs. These CO5BOLD radiation-hydrodynamics simulations, unlike the previous 1D calculations, do not rely on the mixing-length theory for the treatment of convection. The simulations have been employed to compute model spectra and we compared our improved Balmer line profiles to spectroscopic data from the Sloan Digital Sky Survey and the White Dwarf Catalog. The 3D surface gravities are found to be as much as 0.3 dex lower than the values derived from 1D models. The white dwarfs with a radiative and a convective atmosphere have derived mean masses that are the same within 0.01 Msun with our new models, in much better agreement with our understanding of stellar evolution.

315.08 – The white dwarf cooling sequence of the Galactic bulge

Annalisa Calamida[1], Kailash C. Sahu[1], Jay Anderson[1], Stefano Casertano[1], Thomas M. Brown[1], Santino Cassisi[2], Josh Sokol[1], Howard E. Bond[1], Henry C. Ferguson[1], Mario Livio[1], Maurizio Salaris[3], Ivan Ferraro[4], Jeff A. Valenti[1]

1. Space Telescope Science Institute, Baltimore, MD, United States. 2. Osservatorio Astronomico di Teramo - INAF, Teramo, Italy. 3. Astrophysics Research Institute - Liverpool John Moores University, Liverpool, United Kingdom. 4. Osservatorio Astronomico di Roma - INAF, Rome, Italy.

We present F606W,F814W (V,I)-band time-series data of ~1 million stars in the low-reddening Sagittarius window in the Galactic bulge. Images were collected with the Advanced Camera far Surveys (ACS) and the Wide Field Camera 3 mounted on the Hubble Space Telescope. The total field of view is ~ 17x18 arcminutes, which was observed approximately every two weeks for two consecutive years, with the principal aim to detect a hidden population of isolated black holes and neutron stars in the Galactic disk through astrometric microlensing. Here we present some results based on the combined deep images of the four ACS fields. The final photometric catalog of ~ 1 million stars reaches down to V ~ 31 mag. Proper motions were also measured, with an accuracy of better than ~ 0.15 mas/yr at V ~ 26 mag in both coordinates. We were then able to separate disk and bulge stars and obtain a clean bulge color-magnitude diagram. Together with several candidate extreme horizontal branch (EHB) stars we were able to identify for the first time a clearly defined white dwarf (WD) cooling sequence in the bulge. The comparison between theory and observations shows that a fraction of the WDs is systematically redder than the canonical cooling tracks for CO-core DA WDs. This evidence would suggest the presence of He-core WDs in the bulge, formed in close binaries, as has been found in some Galactic globular and open clusters. The presence of close binaries in the EHB and WD bulge population is further supported by the finding of two EHB ellipsoidal variables and a candidate dwarf nova in outburst in one of the ACS fields.

316 – Supernovae & Nebulae III

Oral Session – National Harbor 10 – 08 Jan 2014 10:00 am to 11:30 am

316.01D – Observations of Type Iax Supernovae

Curtis McCully[1], Saurabh Jha[1], Ryan J. Foley[2]
1. Rutgers, The State University of New Jersey, Piscataway, NJ, United States. 2. University of Illinois at Urbana-Champaign, Champaign, IL, United States.

Type Iax supernovae (SNe Iax) are a class of peculiar cousins to normal Type Ia SNe, with SN 2002cx as the prototype. These explosions have photospheric velocities half those of normal SNe Ia, but are otherwise spectroscopically similar at early times. SNe Iax are typically more than ~1 magnitude fainter than normal SNe Ia with similar light curve shapes. These objects depart most dramatically from normal SNe Ia at late epochs, with a slow photometric decline and spectra that are unmatched by any other kind of supernova. I will present Hubble Space Telescope and ground-based optical and near-infrared observations of SN 2005hk and SN 2008A, typical SNe Iax, emphasizing results from late-time data. I will also show new UV observations of the type Iax SN 2013dh, and discuss constraints on the progenitor systems of these peculiar SNe. Recent models of a deflagration explosion in a carbon/oxygen white dwarf that does not completely disrupt the star can match some of the observed properties of SNe Iax, but no published model is consistent with all of the observations.

316.02 – Kepler Supernovae

Robert Olling[1], Edward J. Shaya[1], Richard Mushotzky[1], Armin Rest[2], Bradley E. Tucker[3], Daniel Kasen[4], Steven J. Margheim[5]
1. Univ. Of Maryland, College Park, MD, United States. 2. STScI, Baltimore, MD, United States. 3. Australian National University , Weston Creek, ACT, Australia. 4. Univ Of California, Berkeley , Berkeley, CA, United States. 5. Gemini Obs. , Tuscon, AZ, United States.

We present four supernovae discovered in the Kepler field. Two of these are clearly of Type Ia. The Kepler data show in unprecedented detail the lightcurves from months before to months after the explosions, with a 30 minute cadence. We will summarize implications for SN science and our data reduction procedures.

316.03 – High-Velocity Features in the Spectra of Type-Ia Supernova

Jeffrey M. Silverman[1], G. H. Marion[1], J. C. Wheeler[1], Jozsef Vinko[1, 2]
1. University of Texas at Austin, Austin, TX, United States. 2. University of Szeged, Szeged, Hungary.

Optical spectra of Type-Ia supernovae (SNe Ia) obtained before maximum brightness sometimes show high-velocity features (HVFs). They are most often seen in Si II and Ca II and in the most obvious cases appear as a second, separate absorption feature at ~7000-10000 km/s higher expansion velocity than the more normal photospheric velocity features (PVFs). We explore how to determine the presence or absence of HVFs and how to accurately measure these two components. We investigate how often HVFs occur, at what epochs, and how they evolve with time using a large sample of low-resolution, optical spectra of nearby SNe Ia. Our ongoing study indicates that HVFs are quite common in SNe Ia during the weeks leading up to maximum brightness. Correlations between photometric observables and the strengths and expansion velocities of both HVFs and PVFs are currently being sought. Various explanations for the existence and behavior of the HVFs are being considered, with possibilities including a density enhancement in the outer portion of the SN ejecta or low levels of interaction with circumstellar material.

316.04 – SN 2012fr: A Type Ia Supernova with Extreme High Velocity Features and Stratefied Ejecta

Michael Childress[1, 2], Richard A. Scalzo[1, 2], Stuart Sim[3], Bradley E. Tucker[1, 4], Fang Yuan[1, 2], Brian P. Schmidt[1, 2]
1. Australian National University, Canberra, ACT, Australia. 2. ARC Centre of Excellence for All-Sky Astrophysics (CAASTRO), Sydney, ACT, Australia. 3. Queen's University Belfast, Belfast, Northern Ireland, United Kingdom. 4. University of California, Berkeley, Berkeley, CA, United States.
Contributing teams: Carnegie Supernova Project, PESSTO, Filippenko Supernova Group

SN 2012fr was a luminous normal Type Ia supernova in the nearby barred spiral galaxy NGC 1365. We obtained 65 optical spectra of SN 2012fr from nine telescopes spanning four continents over a two month period beginning two days after the date of explosion. SN 2012fr exhibited extremely strong high-velocity features (HVFs) at early epochs, and exhibits the strongest HVFs amongst a sample of 58 nearby SNe Ia. Clean separation of the HVFs and photospheric velocity features

(PVFs) was facilitated by the narrowness of the PVFs. This narrow line width also revealed a late velocity plateau in lines of intermediate mass elements, which did not manifest for iron group elements, thereby indicating a layering of burning products in the supernova ejecta.

316.05 – Interaction of Type Ia Supernovae With The Circumstellar Environment

Paul Dragulin[1], Peter Hoeflich[1], Alexei Khokhlov[2]
1. Tallahassee, FL, FL, United States. 2. University of Chicago, Chicago, IL, United States.

We present theoretical semi-analytic models for the interaction of stellar winds with the interstellar medium (ISM). To investigate a wide range of possible winds and environments, we developed and employ piecewise, semi-analytical descriptions implemented in our code SPICE assuming spherical symmetry, isothermal winds and power-law ambient density profiles. As one of the many potential applications for SPICE, here we study preconditioning of the environent of thermonuclear supernovae, so called Type Ia Supernovae (SNe~Ia) which are thought to originate from an accreting white dwarf star (WD), so called single degenerate scenario(SD) or two merging White WD, so called double degenerate scenarios (DD). The wind of the progenitor systems may originate from the white dwarf star (WD), a donor star or an accretion disk. The environment is determined by the ISM and/or the wind of the donor star and the progenitor star during a prior epoch. Our free parameters are the a) mass loss, b) wind velocity c) the density of the ISM at a given reference distance, d) (radial power law) density distributions of the ISM, and e) the duration of the wind prior to the supernova explosion. We discuss the observational signatures with respect to light curves and high resolution spectra as tools to probe the environment of SNe~Ia.

316.06 – Pulsating Instability of Turbulent Thermonuclear Flames in Type Ia Supernovae

Alexei Y. Poludnenko[1]
1. Naval Research Lab, Washington, DC, United States.

Presently, one of the main explosion scenarios of type Ia supernovae (SNIa), aimed at explaining both "normal" and subluminous events, is the thermonuclear incineration of a white-dwarf in a single-degenerate system. The underlying engine of such explosions is the turbulent thermonuclear flame. Modern, large-scale, multidimensional simulations of SNIa cannot resolve the internal flame structure, and instead must include a subgrid-scale prescription for the turbulent-flame properties. As a result, development of robust, parameter-free, large-scale models of SNIa crucially relies on the detailed understanding of the turbulent flame properties during each stage of the flame evolution. Due to the complexity of the flame dynamics, such understanding must be validated by the first-principles direct numerical simulations (DNS). In our previous work, we showed that sufficiently fast turbulent flames are inherently susceptible to the development of detonations, which may provide the mechanism for the deflagration-to-detonation transition (DDT) in the delayed-detonation model of SNIa. Here we extend this study by performing detailed analysis of the turbulent flame properties at turbulent intensities below the critical threshold for DDT. We carried out a suite of 3D DNS of turbulent flames for a broad range of turbulent intensities and system sizes using a simplified, single-step, Arrhenius-type reaction kinetics. Our results show that at the later stages of the explosion, as the turbulence intensity increases prior to the possible onset of DDT, the flame front will become violently unstable. We find that the burning rate exhibits periodic pulsations with the energy release rate varying by almost an order of magnitude. Furthermore, such flame pulsations can produce pressure waves and shocks as the flame speed approaches the critical Chapman-Jouguet deflagration speed. Finally, in contrast with the current theoretical understanding, such fast turbulent flames can propagate at speeds, which are much higher than the characteristic speeds of turbulent fluctuations. These effects can qualitatively change the dynamics of the explosion and, therefore, must be properly accounted for in the turbulent-flame subgrid-scale models.

316.07 – Cosmological Constraints Measurements of Type Ia Supernovae Discovered during the first 1.5 Years of the Pan-STARRS1 Survey

Armin Rest[1], Daniel Scolnic[2]
1. Space Telescope Science Institute, Timonium, MD, United States. 2. John Hopkins University, Baltimore, MD, United States.
Contributing teams: Pan-STARRS1 survey

We present griz light curves of 147 spectroscopically confirmed Type Ia Supernovae ($0.03 < z < 0.65$) discovered during the first 1.5 years of the PS1 Medium Deep Survey. The PS1 natural photometric system is determined by a combination of on-site measurements of the instrument response function and spectrophotometric standard star observations. We find that the systematic uncertainties in the absolute calibration are currently 1.2% without accounting for the uncertainty in the HST Calspec definition of the AB system. We discuss our efforts to minimize the systematic uncertainties in the photometry. A Hubble diagram is constructed with a subset of 117 SNe Ia (out of the 147) that pass our light curve quality cuts. We constrain the equation of state parameter w using the PS1 SN Ia, a low-z set of SNe Ia, and external constraints derived from BAO, CMB, and H0.

317 – Time Domain Astronomy, the Large Synoptic Survey Telescope, and Transient Follow-up

Special Session – Potomac Ballroom D – 08 Jan 2014 10:00 am to 11:30 am

Time Domain Astronomy (TDA) has emerged as a major field of Astrophysics, providing data and insights into astrophysical phenomena on timescales of milliseconds to a century. This special session will discuss both current and planned optical TDA surveys and some of the discoveries that on-going programs are making. Full exploitation of these discoveries requires extensive follow-up beyond the initial identification: additional photometry, spectroscopic identification, and observations in wavebands from gamma-rays to radio. The Large Synoptic Survey Telescope expects to start its 10-year mission to image the sky in late 2021. Roughly half the Celestial Sphere will be surveyed in six broad bands, ugrizy, with each patch of sky visited 850 times over the survey lifetime, leading to fundamentally new discoveries in the time domain of the faint universe. The session will conclude with a Panel and audience discussion on how the community can optimize scientific opportunities for TDA in the era of LSST.

317.01 – Synoptic Sky Surveys: Lessons Learned and Challenges Ahead

Stanislav G. Djorgovski[1]
1. Caltech, Pasadena, CA, United States.
Contributing teams: CRTS team

A new generation of synoptic sky surveys is now opening the time domain for a systematic exploration, presenting both great new scientific opportunities as well as the challenges. These surveys are touching essentially all subfields of astronomy, producing large statistical samples of the known types of objects and events (e.g., SNe, AGN, variable stars of many kinds), and have already uncovered previously unknown subtypes of these (e.g., rare or peculiar types of SNe). They are generating new science now, and paving the way for even larger surveys to come, e.g., the LSST. Our ability to fully exploit such forthcoming facilities depends critically on the science, methodology, and experience that are being accumulated now. Among the outstanding challenges the foremost is our ability to conduct an effective follow-up of the interesting events discovered by the surveys in any wavelength regime. The follow-up resources, especially spectroscopy, are already be severely limited, and this problem will grow by orders of magnitude. This requires an intelligent down-selection of the most astrophysically interesting events to follow. The first step in that process is an automated, real-time, iterative classification of transient events, that incorporates heterogeneous data from the surveys themselves, archival information (spatial, temporal, and multiwavelength), and the incoming follow-up observations. The second step is an optimal automated event prioritization and allocation of the available follow-up resources that also change in time. Both of these challenges are highly non-trivial, and require a strong cyber-infrastructure based on the Virtual Observatory data grid, and the various astroinformatics efforts now under way. This is inherently an astronomy of telescope-computational systems, that increasingly depends on novel machine learning and artificial intelligence tools. Another arena with a strong potential for discovery is an archival, non-time-critical exploration of the time domain, with the time dimension adding the complexity to an already challenging problem of data mining of highly-dimensional data parameter spaces.

317.02 – Time-Domain Astrophysics: Results and Lessons from Pan-STARRS

Edo Berger[1]
1. Harvard Univ., Cambridge, MA, United States.

The advent of wide-field optical surveys dedicated to the study of transients has led to a rapid increase in the samples of known events (e.g. supernovae, AGN, flare stars), as well as to the discovery of new classes (e.g. tidal disruption events, ultra-luminous supernovae, fast optical transients). In this talk I will summarize key results from the Pan-STARRS survey, the only existing direct precursor to LSST in terms of cadence, filter set, and depth. I will build on these results to discuss strategies for the identification of exotic transients in the LSST era.

317.03 – Opportunities and challenges for time domain astronomy with LSST

Zeljko Ivezic[1]
1. Univ. of Washington, Seattle, WA, United States.

The Large Synoptic Survey Telescope (LSST) will enable faint optical time-domain astronomy by carrying out an imaging survey covering the sky that is visible from Cerro Pachon in Northern Chile. Of the order thousand 9.6 sq. deg. images (3.2 Gigapix) will be obtained per night using pairs of 15-second back-to-back exposures, with typical 5-sigma depth for point sources of r~24.5 (AB). With close to 1000 observations of a 18,000 sq. deg. region in ugrizy bands over a 10-year period, these data will enable a deep stack across half the sky reaching five magnitudes deeper than the SDSS survey (r~27.5, 5 sigma, point source), and with twice as good seeing (0.7 arcsec median seeing in the r band). The measured and archived properties of newly discovered and known astrometric and photometric transients will be publicly reported within 60 sec after closing the shutter. Automated classification of the expected several million alerts per night, and selection of transient events requiring immediate follow-up, is an outstanding problem for the community. These data will represent a treasure trove for follow-up programs using other ground and space-based telescopes, such as fast-response fast-cadence photometric

observations and spectroscopy, as well as for facilities operating at non-optical wavelengths and for gravitational wave programs. I will describe the relevant data products to be delivered by LSST and will summarize challenges that will need to be addressed by the community at large.

317.04 – Transients and Variable Stars: Followup in the Era of LSST

Lucianne Walkowicz[1]
1. Princeton University, Princeton, NJ, United States.
Contributing teams: the LSST Transients and Variable Stars Science Collaboration

LSST's all-sky coverage, long-term monitoring, and flexible criteria for event identification will revolutionize studies of a wide variety of astrophysical phenomena. LSST will open new a window onto both familiar and exotic transients and variables, from known types in the local universe, to rare and faint transients at cosmological distances. The scientific opportunities afforded by LSST necessarily come with new challenges: in the vast LSST data stream, how does one identify events of interest, and marshal precious observational resources to extract physical understanding? Followup considerations include the required latency between the alert and observations, the intent (detailed characterization versus even discrimination), and scope (e.g. number of objects, magnitude range, sky coverage and observing strategy). "Followup" may also comprise coordinated observations between facilities in different wavebands. In this talk, I discuss the opportunities LSST will provide, the challenges we face and opportunities for community involvement.

318 – Warner Prize: The Origin of Stellar Masses

Plenary Session – Potomac Ballroom A – 08 Jan 2014 11:40 am to 12:30 pm

318.01 – The Origin of Stellar Masses

Mark R. Krumholz[1]

1. University of California, Santa Cruz, Santa Cruz, CA, United States.

The origin of the stellar initial mass function (IMF) is one of the oldest problems in theoretical astrophysics, and one of the most important. The IMF has both a scale-free powerlaw part that appears invariant with star-forming environment, and a characteristic peak at a mass that varies at most weakly. The characteristic mass is also quite special. If it were much lower, then the typical star would never ignite hydrogen; if it were much higher, the typical star would not experience a long phase of stable hydrogen burning. However, there is no obvious reason why the interstellar medium should pick out this special mass range. In this talk, I review models for understanding the origin and near-invariance of the IMF, both the scale-free powerlaw part and the characteristic peak. I discuss what physical ingredients are required for a sensible theory, and I discuss the prospects for building both analytic models and numerical simulations based on those ingredients in the coming decade.

319 – The Hubble and James Webb Space Telescopes Town Hall Meeting

Town Hall – Potomac Ballroom A – 08 Jan 2014 12:45 pm to 01:45 pm

The Hubble Space Telescope is more powerful and productive than ever. Hubble is pressing forward with new instrument capabilities and ambitious observing programs to establish new scientific frontiers. As it has done throughout its history, the next wave of Hubble observations will transform our understanding of the universe, inspire generations of students, and influence popular culture. In this AAS Town Hall, we will feature a short summary of the scientific promise of Hubble for the next several years of Astrophysics, and the current status of its instrumentation. Beyond Hubble, the James Webb Space Telescope will be the most powerful telescope that astronomers have ever constructed, and is essential for answering many of the top science questions outlined in the Astronomy and Astrophysics 2000 and 2010 Decadal Surveys. The observatory made excellent progress in 2013 by achieving several important milestones, including the completion and delivery of all four science instruments, and all of the mirrors, to NASA. JWST has now entered a detailed integration and testing phase, in preparation for the 2018 launch. We will give a short presentation related to the overall status of the JWST program. Following the two updates on Hubble and Webb, we will feature an innovative science talk to be delivered by 2011 Nobel Prize recipient Adam G. Riess on measuring dark energy and the Hubble constant with both telescopes. There will ample time available for audience questions and open discussion. Speaker Summary: Ken Sembach (STScI) - HST Update Eric Smith (NASA HQ) - JWST Update Adam Riess (STScI/JHU) - The Hubble Constant and Dark Energy

320 –

Town Hall – National Harbor 3 – 08 Jan 2014 12:45 pm to 01:45 pm

A joint activity of the National Research Council's Board on Physics and Astronomy and the Space Studies Board, the overarching purpose of the Committee on Astronomy and Astrophysics (CAA) is to support scientific progress in astronomy and astrophysics and assist the federal government in integrating and planning programs in these fields. The CAA provides an independent, authoritative forum for identifying and discussing issues in astronomy and astrophysics between the research community, the federal government, and the interested public. The National Research Council's Committee on Astronomy and Astrophysics requests a town hall at the January 2014 meeting for the committee to communicate directly with the astronomy and astrophysics community to discuss issues the fields are facing and to collect input from the broad community. Encouraged by its engagement with the community at its 2013 AAS Winter Meeting Town Hall, the CAA would like to hold a town hall meeting in 2014 to solicit input from and engage with the astronomy and astrophysics community on the many issues that have arisen in the past year. The CAA is and will continue to deal with a complex set of issues that will affect future NASA, NSF, and DOE research and spending priorities. Involving the broad astronomy community is critical to the CAA's work and will help committee members provide the most informed advice to stakeholders. In addition, the town hall would allow CAA representatives to communicate the committee's recent activities to the community.

321 – AGN Across the Spectrum: II
Oral Session – National Harbor 11 – 08 Jan 2014 02:00 pm to 03:30 pm

321.01D – Probing the Brightest QSOs Though the Spatial Distribution of Galaxies and (Fluorescent) Lya Emitters

Ryan Trainor[1], Charles C. Steidel[1]
1. Caltech, Pasadena, CA, United States.

QSOs are effective tracers of galaxies and black hole evolution over cosmic time, but the most luminous QSOs (L ~ 10^14 Lsun) are extremely rare even at the peak redshifts of black hole growth, 2 < z < 3. I will present detailed probes of such hyperluminous QSOs and their environments at these redshifts using deep surveys of 1558 continuum-selected galaxies (LBGs; R < 25.5) and 890 Lya-emitters (LAEs; NB_Lya < 26.5) selected to lie in the neighborhoods or foreground/background of the QSOs. Using clustering statistics, we derive the halo masses of the QSOs (log M ~ 12.5) and LBGs (log M ~ 11.9) and place their central black holes on the M_DM-M_BH relationship, finding a large discrepancy compared to the estimates at low redshift. Using the sample of LAEs, we present evidence for a QSO-induced fluorescent contribution to their Lya emission, and we constrain the lifetime (1 Myr < t < 20 Myr) and opening angle (theta > 30 degrees) of QSO emission via the 3D distribution of fluorescent Lya emitters. Taken together, these parallel surveys provide a unique window into the production of the most massive black holes and their role in the evolving universe.

321.02 – The Most Bolometrically Luminous Quasars

Amy E. Kimball[1, 2], Mark Lacy[2], Carol J. Lonsdale[2], James J. Condon[2], Roberto Maiolino[3]
1. CSIRO Astronomy and Space Science, Sydney, NSW, Australia. 2. NRAO, Charlottesville, VA, United States. 3. Cavendish Laboratory, Department of Physics, Cambridge, United Kingdom.

I have combined data from sky surveys in the UV to the mid-IR, along with radio and X-ray data, to identify the most luminous quasars in the Universe. The most luminous have bolometric luminosities in the range of several time 10^14 Lsun, and are likely in the midst of a very interesting evolutionary phase of peak black hole growth and strong feedback in their host galaxies. Recent observations of several of these sources with ALMA and the VLA reveal properties of the host galaxies including total star formation activity and bulge kinematics.

321.03D – Diversity in the 2MASS Red AGN Population - Anomalous Reddening and Excess Hot Dust?

Marvin Rose[1, 2]
1. Harvard Smithsonian, Cambridge, MA, United States. 2. University of Sheffield, Sheffield, Yorkshire, United Kingdom.

A key result of the Two Micron All Sky Survey (2MASS) was the discovery of a population of AGN that are redder than UV/optical selected AGNs at near-IR wavelengths. I investigated the nature of 2MASS red AGN in this thesis. I present WHT ISIS optical spectra and near- to mid-IR (WISE) photometry for a representative sample of 29 nearby (z<0.28) 2MASS-selected AGN with J-K > 2.0, comparing them with comparison samples of UV/optical selected AGN. The spectra show a remarkable variety, including: (1) moderately reddened type 1 objects (58%), (2) type 1 objects similar to traditional UV/optically selected AGN, (3) narrow-line Seyfert 1s (14%), (4) type 2 AGN (21%) and (5) HII/composite objects (7%). Although most show Balmer decrements suggesting significant optical reddening (median E(B-V) ~ 0.52), some (24%) objects show little or no reddening (E(B-V)< 0.1). The near- to mid-IR photometry reveal that a fraction (26%) of the broad-line 2MASS objects have unusually blue 2.17-3.4 micron colors compared to the rest. I suggest that their red near-IR colors are due to emission by an unusually high covering factor of hot dust. Overall, a variety of mechanisms is required to explain the red 2MASS AGNs, however, based on the [OIII] outflow properties, the incidence of NLS1, and the distribution of Eddington ratios, I find no clear evidence that the 2MASS objects are young, dust enshrouded AGN.

321.04 – Evidence for Large Temperature Fluctuations in Quasar Accretion Disks from Spectral Variability

John J. Ruan[1], Scott F. Anderson[1], Eric Agol[1], Jason Dexter[2]
1. University of Washington, Seattle, WA, United States. 2. UC Berkeley, Berkeley, CA, United States.

The well-known bluer-when-brighter trend observed in quasar variability is a signature of the complex processes in the accretion disk, and can be a probe of the quasar variability mechanism. Using a sample of 604 variable quasars with repeat spectra in SDSS-I/II, we construct difference spectra to investigate the physical causes of this bluer-when-brighter trend. The continuum of our composite difference spectrum is well-fit by a power-law, with a spectral index in excellent agreement with previous results. We measure the spectral variability relative to the underlying spectra of the quasars, which is independent

of any extinction, and compare to model predictions. We show that our SDSS spectral variability results cannot be produced by global accretion rate fluctuations in a thin disk alone. However, we find that a simple model of a inhomogeneous disk with localized temperature fluctuations will produce power-law spectral variability over optical wavelengths. We show that the inhomogeneous disk will provide good fits to our observed spectral variability if the disk has large temperature fluctuations in many independently varying zones, in excellent agreement with independent constraints from quasar microlensing disk sizes, their strong UV spectral continuum, and single-band variability amplitudes. Our results provide an independent addition to the mounting evidence that quasar accretion disks have large localized temperature fluctuations.

321.05D – Probing the Central Regions of Active Galactic Nuclei

Anne M. Lohfink[1], Christopher S. Reynolds[1], Richard Mushotzky[1], Michael Nowak[2]
1. University of Maryland, College Park, MD, United States. 2. MIT Kavli Institute, Cambridge, MA, United States.

AGN influence their surroundings via feedback processes and contribute significantly to the evolution of their host galaxies. While this is well established today, our understanding of these processes is incomplete. A missing crucial piece is an understanding of the processes in the heart of the AGN close to the black hole, where a vast majority of the energy is released. My talk explores these central regions in several AGN, both radio-quiet and radio-loud, using the powerful tool of X-ray spectroscopy. I will describe some of the problems (and their solutions) we encountered when trying to study the fundamental parameters, such as black hole spin, which shape these central regions. For the Seyfert 1 galaxy Fairall 9, we find that the accretion disk parameters are dependent on the spectral decomposition. To get a unique decomposition, we need to understand the soft X-ray excess seen in many AGN but not understood to date. Our analysis hints at the soft excess being partially a separate spectral component such as Comptonization. We tested this hypothesis with studies of the UV--X-ray correlation from a Swift monitoring of the source. We obtained an unambiguous detection of both the correlation and previously undetected 4-day time scale UV variability. The confirmation of our X-ray results using UV photometry shows great promise as a proxy for the detection of a Comptonization soft excess in AGN. The second part of my talk will focus on the formation of jets in AGN which is another vital piece in the feedback puzzle. We study the bright radio-loud AGN 3C120, in which a clear disk-jet connection has been established. We will present the best snapshot to date of the central engine structure in any radio-loud AGN, taken with Suzaku in February 2012. To place this deep Suzaku stare into the context of the disk-disruption/jet-ejection cycles displayed by this object, we also analyzed a monitoring of the source in the UV/X-ray (Swift) and radio bands (VLBA). Our observations confirm the current idea of jet formation, which links the ejection of a new jet knot to a disturbance/disruption of the inner parts of the accretion disk.

322 – Astronomy Education Research
Oral Session – Maryland 1 – 08 Jan 2014 02:00 pm to 03:30 pm

322.01 – The Effect of Stereoscopic ("3D") vs. 2D Presentation on Learning through Video and Film

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Two Eyes, 3D is a NSF-funded research project into the effects of stereoscopy on learning of highly spatial concepts. We report final results on one study of the project which tested the effect of stereoscopic presentation on learning outcomes of two short films about Type 1a supernovae and the morphology of the Milky Way. 986 adults watched either film, randomly distributed between stereoscopic and 2D presentation. They took a pre-test and post-test that included multiple choice and drawing tasks related to the spatial nature of the topics in the film. Orientation of the answering device was also tracked and a spatial cognition pre-test was given to control for prior spatial ability. Data collection took place at the Adler Planetarium's Space Visualization Lab and the project is run through the AAVSO.

322.02 – Visualizing Moon Phases in the Classroom with WorldWide Telescope

Patricia S. Udomprasert[1], Alyssa A. Goodman[1], Susan Sunbury[1], Zhihui Zhang[1], Philip M. Sadler[1], Mary E. Dussault[1], Erin Lotridge[1], Jonathan Jackson[1], Ana-Maria Constantin[1]
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We report results from an NSF-funded project to build, test, and research the impact of a WorldWide Telescope Visualization Lab (WWT Vizlab), meant to offer learners a deeper physical understanding of the causes of the Moon's phases and eclipses. The Moon Phases VizLab is designed to promote accurate visualization of the complex, 3-dimensional Earth-Sun-Moon relationships required to understand the Moon's phases, while also providing opportunities for middle school students to practice critical science skills, like using models, making predictions and observations, and linking them in evidence-based explanations. In the Moon Phases VizLab, students use both computer-based models and lamp + ball physical models. The VizLab emphasizes the use of different scales in models, why some models are to scale and some are not, and how choices we make in a model can sometimes inadvertently lead to misconceptions. For example, textbook images almost always depict the Earth and Moon as being vastly too close together, and this contributes to the common misconception that the Moon's phases are caused by the Earth's shadow. We tested the Moon Phases VizLab in two separate phases. In Phase 1 (fall 2012), we compared learning gains from the WorldWide Telescope (WWT) VizLab with a traditional 2-dimensional Moon phases simulator. Students in this study who used WWT had overall higher learning gains than students who used the traditional 2D simulator, and demonstrated greater enthusiasm for using the virtual model than students who used the 2D simulator. In Phase 2 (spring 2013), all students in the study used WWT for the virtual model, but we experimented with different sequencing of physical and virtual models in the classroom. We found that students who began the unit with higher prior knowledge of Moon phases (based on the pre-unit assessment) had overall higher learning gains when they used the virtual model first, followed by the physical model, while students who had lower prior knowledge benefited from using the physical model first, then the virtual model.

322.03 – How Faculty can Affect Student Texting, Distraction, Grades, and Attitudes

Douglas K. Duncan[1], Angel Hoekstra[1], Bethany Wilcox[1]
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There is considerable pressure on faculty members to use technology in teaching. Students also bring technology into class in the form of laptop computers, smart phones, and iPads. Does this technology increase or decrease learning? We report two years of data studying 14 different classes with a total of approximately 1200 students. We find that, on the average, approximately 70% of students use their own digital devices during class and 30% do not. The grades earned by the former group average nearly half a grade point average lower than the non-use group. Faculty policies are found to dramatically influence student behavior. Extensive student interview data will be reported that shows that students expect faculty members to set technology policies and summarizes their attitudes about technology use.

322.04 – Assessment of Teaching Methods and Critical Thinking in a Course for Science Majors

Angela Speck[1], Lanika Ruzhitskaya[1], Alan G. Whittington[1]
1. Univ. of Missouri, Columbia, MO, United States.

Ability to think critically is a key ingredient to the scientific mindset. Students who take science courses may or may not be

predisposed to critical thinking – the ability to evaluate information analytically. Regardless of their initial stages, students can significantly improve their critical thinking through learning and practicing their reasoning skills, critical assessments, conducting and reflecting on observations and experiments, building their questioning and communication skills, and through the use of other techniques. While, there are several of teaching methods that may help to improve critical thinking, there are only a few assessment instruments that can help in evaluating the efficacy of these methods. Critical thinking skills and improvement in those skills are notoriously difficult to measure. Assessments that are based on multiple-choice questions demonstrate students' final decisions but not their thinking processes. In addition, during the course of studies students may develop subject-based critical thinking while not being able to extend the skills to the general critical thinking. As such, we wanted to design and conduct a study on efficacy of several teaching methods in which we would learn how students' improve their thinking processes within a science discipline as well as in everyday life situations. We conducted a study among 20 astronomy, physics and geology majors-- both graduate and undergraduate students-- enrolled in our Solar System Science course (mostly seniors and early graduate students) at the University of Missouri. We used the Ennis-Weir Critical Thinking Essay test to assess students' general critical thinking and, in addition, we implemented our own subject-based critical thinking assessment. Here, we present the results of this study and share our experience on designing a subject-based critical thinking assessment instrument.

322.05 – Science Literacy's Neglected Twin: Numeracy

Katherine B. Follette[1], Donald W. McCarthy[1], Erin F. Dokter[1], Sanlyn Buxner[1]
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The abysmal numerical skills of undergraduates is a common lament among science educators. In recent years, it has become increasingly clear that this lack of skill is not mitigated over the course of an undergraduate education and is carried over into the college-educated general population in the form of widespread quantitative illiteracy. Consequently, the general public's ability to do simple arithmetic, read graphs and charts, interpret statistics and put numbers into context is lacking. This makes them vulnerable to false advertising and pseudoscience and harms their ability to be savvy consumers, discerning voters and conscientious citizens. More than 10% of all college students take an introductory Astronomy course, and the math-phobic are particularly drawn to Astronomy, believing it to be a "non-quantitative" science. We as astronomy educators thus have a unique ability to help with the problem of quantitative illiteracy by showing our students how numbers and numerical language can be used in context to understand science, to make, support and discount arguments, and to interpret information in the media. The educational component of my dissertation has been focused on investigating whether introductory astronomy courses for non-majors can improve student skills and, perhaps even more importantly, improve student attitudes towards the numerical and its role in daily life. This research has included the development of a 25 question survey instrument administered to more than 1000 students in 17 classrooms. I will report on the development of the instrument, as well as interesting preliminary results, including students' overrating of their own abilities and data showing that it is possible to improve student attitudes, if not skills, by consciously emphasizing the numerical in the science classroom.

322.06 – CHARACTERIZATION AND MEASUREMENT OF INTRODCUTORY COLLEGE ASTRONOMY AND PHYSICS STUDENT UNDERSTANDING OF NEWTONIAN GRAVITY

Kathryn Williamson[1]
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The topic of Newtonian gravity offers a unique perspective from which to investigate and encourage conceptual change because it is something with which everyone has daily experience, and because it is taught in two courses that reach a variety of students – introductory college astronomy ('Astro 101') and physics ('Phys 101'). Informed by the constructivist theory of learning, this study characterizes and measures Astro 101 and Phys 101 students' understanding of Newtonian gravity within four conceptual domains – Directionality, Force Law, Independence of Other Forces, and Threshold. A phenomenographic analysis of student-supplied responses to open-ended questions about gravity resulted in characterization of students' alternative models and misapplications of the scientific model. These student difficulties informed the development of a multiple-choice assessment instrument, the Newtonian Gravity Concept Inventory (NGCI). Classical Test Theory (CTT), student interviews, and expert review show that the NGCI is a reliable and valid tool for assessing both Astro 101 and Phys 101 students' understanding of gravity. Furthermore, the NGCI can provide extensive and robust information about differences between Astro 101 and Phys 101 students and curricula. Comparing and contrasting CTT values and response patterns shows qualitative differences in each of the four conceptual domains. Additionally, performing an Item Response Theory (IRT) analysis calibrates item parameters for all Astro 101 and Phys 101 courses and provides Newtonian gravity ability estimates for each student. Physics students show significantly higher pre- and post-instruction IRT abilities than astronomy students, but they show approximately equal gains. Linear regression models that control for student characteristics and classroom dynamics show that: (1) differences in post-instruction abilities are most influenced by students' pre-instruction abilities and the level of interactivity in the classroom, and (2) there is no differential effect of the astronomy curriculum compared to the physics curriculum on student's overall post-instruction Newtonian gravity abilities.

322.07 – The Collaboration of Astronomy Teaching Scholars (CATS) – Reporting from the Nationion's Largest College-Level, Astronomy Education Research Initiative.

Edward E. Prather[1], Gina Brissenden[1], Chris D. Impey[2], Kevin M. Lee[3]

1. Center for Astronomy Education (CAE) Univ. of Arizona, Tucson, AZ, United States. 2. Steward Observatory, Univ. of Arizona, Tucson, AZ, United States. 3. Univ. of Nebraska-Lincolin, Lincolin, NE, United States.

Contributing teams: Collaboration of Astronomy Teaching Scholars (CATS)

The NSF CCLI Phase III Collaboration of Astronomy Teaching Scholars (CATS) National Implementation Program for Learner-Centered Astronomy Teaching began as an ambitious and far-reaching effort focused on building and mobilizing a community of teaching scholars who are engaged with designing, disseminating, and institutionalizing innovative and effective approaches to the teaching and learning of undergraduate Earth, Astronomy, and Space Science. The goals for the CATS program are to increase the number of faculty who embrace and successfully implement learner-centered astronomy teaching strategies, and who treat their teaching as a scholarly endeavor, by systematically studying the teaching and learning in their own classrooms and expanding the astronomy edcuation literature base by publishing the results of their community-focused, national-level, collaborative research projects. Led by members of the Center for Astronomy Education (CAE), in Steweard Observatory, at the University of Arizona, CATS has developed into a sustainable national collaboration bringing together the efforts and infrastructure of hundreds of college and university faculty, postdocs, and graduate and undergraduate students from institutions all across the United States. In this talk, I will report on the research projects, people, and transformations of undergraduate college-level astronomy teaching and learning that have been achieved during the first 6 years of CATS. This material is based in part upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, & conclusions or recommendations expressed in this material are those of the authors & do not necessarily reflect the views of the National Science Foundation.

322.08 – Findings from Five Years Investigating Science Literacy and Where Students Get their Information about Science

Sanlyn Buxner[1], Chris D. Impey[2], Megan N. Nieberding[2], James M. Romine[2], Jessie C. Antonellis[4], Jenna Llull[3], Kitina Tijerino[2]

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Contributing teams: Collaborations of Astronomy Teaching Scholars (CATS), Steward Observatory, University of Arizona

Supported by funding from NSF, we have been investigating the science literacy of undergraduate students using data collected from 1980 -2013. To date, we have collected over 12,000 surveys asking students about their foundational science knowledge as well as their attitudes towards science and technology topics. In 2012, we began investigating where students get their information about science and we have collected 30 interviews and almost 1000 survey responses. Our findings reveal that students' science literacy, as measured by this instrument, has changed very little over the 23 years of data collection despite major educational innovations offered to students. A fraction of students continue to hold onto non-scientific beliefs, coupled with faith-based attitudes and beliefs, which are resistant to formal college instruction. Analysis of students' open-ended responses show that although students use words often associated with science, they lack understandings of key aspects of science including the importance of evidence to support arguments and the need for replication of results. These results have important implications about how we teach science and how we assess students' scientific understandings during class. Our recent work has shown that students use online sources to gain information about science for classes their own interests. Despite this, they rate professors and researchers as more reliable sources of scientific knowledge than online sources. This disconnect raises questions about how educators can work with students to provide knowledge in ways that are both accessible and reliable and how to help students sort knowledge in an age where everything can be found online. This material is based in part upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

322.09 – A Research-Informed Approach to Teaching About Light & Matter in STEM Classrooms

Seth D. Hornstein[1], Colin S. Wallace[2], Wayne M. Schlingman[1], Edward E. Prather[2]

1. University of Colorado Boulder, Boulder, CO, United States. 2. Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, Tucson, AZ, United States.

In collaboration with the National Radio Astronomy Observatory (NRAO), we have engaged in a research and curriculum development program to bring the detailed science of light and matter into STEM classrooms. Typical Astro 101 classes often discuss emission/absorption spectra with reference to the Bohr model only and teach radiation as produced/absorbed only by electron transitions. We present here curricula developed to highlight other emission/absorption phenomena (specifically those produced by rotational/vibrational molecular transitions as well as synchrotron radiation.) Appropriate for physical science classrooms from middle school to the introductory college level, the learner-centered active engagement activities we are developing are going through an iterative research and assessment process to ensure that they enable students to achieve increased conceptual understandings and reasoning skills. In this talk, we will report on our development process for a suite of activities, including lecture slides, Think-Pair-Share questions, assessment questions and a new Lecture-Tutorial that help students learn about these other important emission models.

323 – Binary Systems

323.01D – A holistic view of a black hole binary: bringing together spectral, timing, and polarization analysis of Cygnus X-1

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The microquasar Cygnus X-1 is a persistent high mass X-ray binary, consisting of an O-type supergiant and a stellar mass black hole, and therefore one of those systems which are often considered downscaled versions of AGN, an analogy supported in Cyg X-1 by observations of radio jets. The size and proximity of such systems allow us to observe phenomena on time-scales which are not accessible in their supermassive siblings. Cyg X-1 shows distinct X-ray states, characterized by X-ray spectral and timing properties. Radio behavior is strongly correlated with the X-ray states and a jet-break exists in the mid-IR range in the hard state. The source state is therefore essential for the interpretation of data at all wavelengths. For most observations lacking broadband X-ray coverage, however, the exact state determination proves challenging. In this work, I will present a recently developed novel approach that uses data from all sky monitors such as RXTE-ASM, MAXI, Swift-BAT, and Fermi-GBM to define states and state transitions on a timescales of a few hours over a period of more than 17 years. This approach can be used to investigate the context of high resolution observations of Cyg X-1 with Chandra and XMM, and to conduct state-resolved polarization analysis with INTEGRAL. I then combine spectral and model-independent X-ray timing analysis of over 1900 RXTE orbits over 14 years and investigate the evolution of Fourier-dependent timing parameters such as power spectra, coherence, and time lag at different photon energies over all spectral states. Results include a correlation between the shape of the power and time lag spectra in all hard and intermediate states, a photon-energy dependent increase of the fractional rms in the soft state, and a strong energy-dependency of the power spectra shapes during state transitions. The findings are crucial for constraining physical models for accretion and ejection in compact objects and for comparisons with other accreting objects, especially AGN, since timescales and energies in accreting black holes scale with mass so that observations at the same energies may probe different physical processes therefore show different spectral and timing behavior.

323.02 – Emphasize the difference: On the energy dependance of power spectral states in Black Hole X-ray Binaries

Holger Stiele[1], Wenfei Yu[1]

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Transient black hole X-ray binaries usually evolve through different energy spectral states that show characteristic spectral and variability properties. These characteristics mainly resulted from the energy spectra and the power density spectra obtained by the RXTE in the energy band above 3 keV. This picture has been challenged through our recent study on MAXI J1659152, in which we found a clear energy dependence of the power spectral state; the thermal disk spectral component in the hard and the intermediate state is of a power-law noise with a possible cut-off at a frequency below the characteristic frequencies of the band-limited noise and QPOs seen simultaneously in the Comptonized component, which is similar to the power spectrum of the soft state. Here, we present the results of our comprehensive study of archival XMM-Newton observations of black hole X-ray binaries, which comprises GRS 1915+105, GX 3394, H1743322 and other sources. For the observations of GRS 1915+105 in the "plateau" state we will discuss the overall shape of the power density spectra related to the noise component and the presence or absence of quasi-periodic oscillations in different energy bands. Furthermore, we will present a summary of the power density spectra and related time lags in the observations of GX 3394. The presence of quasi-periodic oscillations and band-limited noise in the power density spectra above ~2 keV and the simultaneous domination by a power-law noise in the power density spectra at lower energies imply that the quasi-periodic oscillations and the band-limited noise are in the Comptonized component and the optically thick disk contributes to a power-law noise which is independent of the energy spectral state. We will discuss the implications of this finding for the picture of the accretion geometry in black hole X-ray binaries.

323.03 – Improved Constraint on the Mass of the Black Hole in Nova Muscae 1991

Jianfeng Wu[1], Jeffrey E. McClintock[1], Danny Steeghs[2, 1], Penelope Longa[2], Manuel Torres[3], Luis C. Ho[4], Paul Callanan[5], Mark Reynolds[6], Jerome A. Orosz[7], Peter Jonker[3, 1]

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Mass is the fundamental parameter of an astrophysical black hole. An accurate value of mass is a prerequisite for

determining a black hole's spin via the continuum-fitting method, while knowledge of both mass and spin completely describes a black hole. Previous dynamical analyses have established that the compact primary in Nova Muscae 1991 (GS 1124-683) is a black hole. In this work, we utilize 72 high resolution Magellan Echelle (MagE) spectra to significantly improve the precision of the mass measurement for Nova Muscae 1991. The spectra were taken on two consecutive nights and span the full 11.4-hour orbital cycle; 70 standard-star template spectra were also taken with the same instrument configuration. The radial velocities of Nova Muscae 1991 are derived by cross-correlating the object spectra with the spectrum of the (K3 V) template star that yielded the statistically most significant cross correlations. Analysis of the data for several echelle orders covering the wavelength range 4100--7300 A provides consistent results for the radial velocity amplitude with a precision of approximately 2 km/s (comparing to ~7 km/s in previous works), which significantly tighten the constraint on the mass function of Nova Muscae 1991.

323.04 – Direct Constraints on the Evolution of LMXBs from Deep Chandra and HST Observations of Nearby Early-Type Galaxies

Bret Lehmer[1,2], Matthew Berkeley[2], D. M. Alexander[3], Antara Basu-Zych[2], Franz E. Bauer[4], W. N. Brandt[5], Tassos Fragos[6], Ann E. Hornschemeier[2], Leigh Jenkins[2], Vassiliki Kalogera[7], Andrew Ptak[2], Gregory R. Sivakoff[8], Panayiotis Tzanavaris[2], Mihoko Yukita[2], Andreas Zezas[9]
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Studies of X-ray binary populations in galaxies allow us to gain insight into the key factors contributing to the formation and evolution of compact objects, the stars involved in the accreting binary phase, and their associated remnants (e.g., millisecond pulsars and compact-object binaries). Early-type galaxies contain predominantly old stars (3-12 Gyr) and have X-ray emission dominated by low-mass X-ray binary (LMXB) populations. I will present results from deep Chandra and HST observations of three nearby early-type galaxies (NGC 3115, 3379, and 3384) that have luminosity-weighted stellar ages covering the range of ~3-10 Gyr. These data allow for the clean identification of field LMXB populations (i.e., sources not coincident with globular clusters), and provide unique measurements for how the field LMXB X-ray luminosity function evolves with time. Leading X-ray binary population synthesis models predict that field LMXB populations will be more prevalent and luminous in the younger early-type galaxies. For the first time, we can unambiguously confront these models and provide important new insight into the formation and evolution of LMXBs.

323.05 – Multi-wavelength Observations of the Binary System PSR B1259−63/LS 2883 Around the 2010-2011 Periastron Passage

Kent S. Wood[1], Masha Chernyakova[2,3], Aous Abdo[4], Andrii Neronov[5], M. V. McSwain[6], J. Moldon[7,8], M. Ribo[7], J. M. Paredes[7], I. Susch[9,10], M. de Naurois[12], U. Schwanke[11], Y. Uchiyama[13], Simon Johnston[14], S. Chaty[15,16], Alexis Coleiro[15], D. Malyshev[17], Iu Babyk[2,3]
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We report on multi-wavelength observations from radio to TeV ?-rays of the 2010-2011 periastron passage of the binary system PSR B125963, which is a unique high-mass ?-ray emitting binary system with a young pulsar companion. Observations with the Fermi Gamma-ray Space Telescope revealed an unexpected GeV ?-ray flaring activity of the system, reaching the spin-down luminosity of the pulsar, around 30 days after periastron.We combine the GeV data with data in other wavebands with the goal of clarifying the origin of the flare. There are no clear signatures of variability at radio, X-ray and TeV energies at the time of the GeV flare. Our optical spectroscopic monitoring reveals clear variability around periastron in the Hα emission line, which is probably due to the gravitational interaction between the pulsar and the circumstellar disk.

Although the influence of the pulsar wind cannot be discarded, it does not seem to be predominant. The equivalent width of Hα grows from a few days before periastron until a few days later, and decreases again between 18 and 46 days after periastron. In near infrared we also observe the similar decrease of the equivalent width of Br? line between the 40th and 117th day after the periastron. Assuming an idealized disk, this behaviour of Hα line represents an increase of density, mass and size of the disk, followed by a decrease in the same parameters. Based on this, we speculate on the possibility that the GeV flare is directly related to the decrease of the disk size, probably due to the gravitational influence of the pulsar or to the pressure of the pulsar wind. We discuss possible physical mechanisms of the highenergy ?-ray flare of the outflow at the moment of disruption of the equatorial disk of the Be star. On the other hand, based on high resolution interferometric radio observations, we show for the first time unambiguous evidence of the extended radio emission trailing the position of the pulsar, as would be expected in a cometary tail scenario. New multi-wavelength observations are needed to further improve our knowledge on the physics behind the production of the extreme GeV flare observed after the periastron passage.

323.06 – Hoyle-Lyttleton Accretion from a Planar Wind

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Two-dimensional hydrodynamic simulations of Hoyle-Lyttleton accretion have informed predictions about the evolution of wind-driven accretion systems for over two decades. These simulations frequently exhibit dramatic nonlinear behavior such as the flip-flop instability and the formation of transient accretion disks. During disk accretion, the mass accretion rate is suppressed and angular momentum accretion occurs at quasi-Keplerian rates. These results have been used to interpret neutron star accretion from the equatorially enhanced wind of a Be star in Be/X-ray Binaries. We employ large-scale hydrodynamic simulations to investigate whether the flip-flop instability is possible in three dimensions or is simply a consequence of the restrictions on a 2D flow. We do not observe the flip-flop instability in 3D for any values of the wind scale height or density. Moreover, the angular momentum vector of the accreting gas is typically found to be in the plane of the disk wind rather than perpendicular to it as one might expect based on the results of 2D planar simulations. We measure large-scale asymmetries about the plane of the disk wind that arise due to rotational flow near the accretor. Gas is driven above and below the plane, where it interacts with the bow shock and results in a time-varying shock structure. Winds with scale heights of 0.25 R_a enter locked rotation modes that remain stable for the duration of our computational runs. During this phase, the mass accretion rate is suppressed by up to two orders of magnitude below the analytical prediction and angular momentum accretion occurs at sub-Keplerian values.

323.07 – Formation and Evolution of the SS 433 Jets

Herman L. Marshall[1], Sebastian Heinz[2], Norbert S. Schulz[1]
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We present observations and modeling of the SS 433 relativistic jets based on contemporaneous X-ray, optical, and VLBA observations. The X-ray and optical emission line regions are found to be related but not coincident as the optical line emission persists for days while the X-ray emission lines fade in less than 5000 s. The line Doppler shifts from the optical and X-ray lines match well, indicating that they are less than 3e14 cm apart. The jet Doppler shifts show aperiodic variations that could result from shocks in interactions with the local environment. These perturbations are consistent with a change in jet direction but not jet speed. We present limits on the jet length and models of the jets that involve semi-relativistic shock heating and subsequent radiative and adiabatic cooling.

323.08 – Superorbital Periodic Modulation in Wind-Accretion High-Mass X-ray Binaries from Swift BAT Observations

Robin H. Corbet[1,2], Hans A. Krimm[3,2]

1. UMBC, Greenbelt, MD, United States. 2. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 3. Universities Space Research Association, Columbia, MD, United States.

We report the discovery using data from the Swift Burst Alert Telescope (BAT) of superorbital modulation in the wind-accretion supergiant high-mass X-ray binaries 4U 1909+07 (= X 1908+075), IGR J16418-4532, and IGR J16479-4514. Together with already known superorbital periodicities in 2S 0114+650 and IGR J16493-4348, the systems exhibit a monotonic relationship between superorbital and orbital periods. These systems include both supergiant fast X-ray transients (SFXTs) and classical supergiant systems, and have a range of inclination angles. This suggests an underlying physical mechanism which is connected to the orbital period. In addition to these sources with clear detections of superorbital periods, IGR J16393-4643 (= AX J16390.4-4642) is identified as a system that may have superorbital modulation due to the coincidence of low-amplitude peaks in power spectra derived from BAT, RXTE PCA, and INTEGRAL light curves. 1E 1145.1-6141 may also be worthy of further attention due to the amount of low-frequency modulation of its light curve. However, we find that the presence of superorbital modulation is not a universal feature of wind-accretion supergiant X-ray binaries. Two suggested mechanisms to drive superorbital modulation are pulsations in the primary star and a 3 body system. However, both of these models appear to have problems and detailed multiwavelength data over a superorbital cycle are required to investigate the cause(s) of the modulation.

324 – Evolution of Galaxy Mergers
Oral Session – National Harbor 2 – 08 Jan 2014 02:00 pm to 03:30 pm

324.01 – Galaxy Mergers on a Moving Mesh

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Galaxy mergers have been studied for decades. However, recent work has demonstrated that the most-commonly used techniques, smoothed-particle hydrodynamics (SPH) and adaptive mesh refinement, suffer from numerical inaccuracies that can potentially jeopardize the results of simulations performed with those techniques. Fortunately, the recently developed moving-mesh hydrodynamics code Arepo does not suffer from this inaccuracies. I will present the results of a comparison of galaxy merger simulations performed with both the SPH code Gadget-3 and Arepo and discuss under what conditions SPH is reasonably accurate and when it is not.

324.02D – A Pipeline for Constructing A Catalog of Multi-Method Models of Interacting Galaxies

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Galaxies are a fundamental unit of matter for describing the large-scale structure of the universe. One of the major processes affecting the formation and evolution of galaxies are gravitational interactions. These interactions can including tidal distortion, mass transfer, and even mergers. In any hierarchical model mergers are the key mechanism in galaxy formation and evolution. Computer simulations of interacting galaxies have evolved in the last four decades from simple restricted three-body algorithms to full n-body gravity models. These codes often included sophisticated physical mechanisms such as gas dynamics, supernova feedback, and central black holes. As the level of complexity increases so does the amount of computational resources needed. These advanced simulations are often used in parameter studies of interactions. They are usually only employed in an ad hoc fashion to recreate the dynamical history of specific sets of interacting galaxies. These models are often created with only a few dozen to a few hundred sets of initial conditions being attempted. This dissertation presents a pipeline for modeling specific interacting galaxies in bulk. The process begins with a simple image of the current disturbed morphology and an estimate of distance to the system and mass of the galaxies. With the use of an updated restricted three-body simulation code and the help of Zooniverse volunteers, the pipeline is able to sample hundreds of thousands of sets of initial conditions for each system. Through the use of a convenient interface and innovative scoring algorithm, the pipeline aids researchers in identifying the best set of simulation parameters. This dissertation provides a successful recreation of the disturbed morphologies of over 60 pairs of interacting galaxies. The pipeline also provides for examining the level of convergence and uniqueness of the dynamical properties of each system. By creating a population of models for actual systems, the current research is able to compare simulation-based and observational values on a larger scale than previous efforts. Several potential relationships between star formation rate and dynamical time since closest approach are presented.

324.03 – Galaxy Pairs in the Galaxy And Mass Assembly (GAMA) Survey

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Contributing teams: GAMA Survey Team

I present preliminary results showing how star formation rates of galaxies depend on their local and global environments. We identify how galaxies in pairs behave whether the pair is isolated or inside of a larger group of galaxies, compared to control samples of non-paired galaxies in similar global environments.

324.04 – Over the Peak: Full Spectrum Far-Infrared Velocity-Resolved Spectroscopy of Three Extreme Gas-Rich Mergers

Jacqueline Fischer[1], Eduardo González-Alfonso[2], Eckhard Sturm[3], Javier Graciá-Carpio[3], Emil Polisensky[1], Nicholas Abel[4], Steve Hailey-Dunsheath[5], Sylvain Veilleux[6], Marcio Melendez[6], Aprajita Verma[7], Albrecht Poglitsch[3], Alessandra Contursi[3]
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We present a comparison of the complete Herschel/PACS velocity-resolved far-infrared spectroscopy of the (U)LIRGs Arp 220, Mrk 231, and NGC 6240. Based on these spectra, the three galaxy systems appear to embody very different stages of gas-rich galaxy merging. While the spectrum of the type 1, low-ionization broad absorption line (LoBAL) ULIRG Mrk 231 bears witness to both a high velocity, massive molecular outflow and a rotating torus or thick disk that are traced by radiatively excited OH, H_2O, OH^+, H_2O^+ and other molecules, in the ULIRG Arp 220 these species trace an interstellar medium that appears dominated by rotation and whose line of sight outflow is characterized by lower velocities. In both galaxies, these species trace the outer "atmospheres" of an interstellar medium that is optically thick even at far-infrared wavelengths, commensurate with the strong line deficits in their measured fine-structure line fluxes. In contrast, while the far-infrared spectrum of the X-ray bright, dual AGN LIRG NGC 6240 is also characterized by a high-velocity molecular outflow traced by ground-state lines of OH, it is dominated by strong atomic fine-structure lines and high-J CO line emission indicative of lower far-infrared obscuration and radiation densities. We compare the fine-structure line strengths and the derived molecular column densities of some of the species traced by the PACS spectra with the predictions of the Cloudy spectral synthesis code to quantitatively analyze the conditions in the interstellar media of these three (U)LIRGs and to view them in the context of simulations of gas-rich galaxy mergers.

324.05 – Nuclear Disks in Gas-Rich Galaxy Mergers

Anne Medling[1, 2], Vivian U[3, 6], Javiera Guedes[4], Claire E. Max[2], Lucio Mayer[4], Lee Armus[5], Bradford Holden[2], Rok Roskar[4], David B. Sanders[6]
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We present near-IR integral field spectroscopy of the central kiloparsec of nearby luminous and ultra-luminous infrared galaxies undergoing major mergers, drawn from the GOALS survey (goals.ipac.caltech.edu). These observations were taken with OSIRIS assisted by the Keck I and II Adaptive Optics systems, providing resolutions of a few tens of parsecs. The resulting kinematic maps reveal gas disks in 16 out of 18 nuclei and stellar disks in 12 out of 12 nuclei. At late stages of mergers, these disks are young (<30 Myr according to the depth of the CO bandhead at 2.292 microns) and likely formed as gas disks which became unstable to star formation during the merger. At earlier stages of mergers, the disks seen are larger and likely are remnants of the galactic disks that have not yet been completely disrupted by the merger. On average, these disks have effective radii of a few hundred parsecs, masses between 10^8 and 10^10 Msun, and v/sigma between 1 and 4. These disk properties agree well with those seen in hydrodynamic simulations of gas-rich mergers that include a multiphase interstellar medium. The large quantity of gas found in these disks likely also has a significant effect on the formation and merger timescales for binary black holes.

324.06 – The Origin and Evolution of (Ultra)Luminous Infrared Galaxies Over Cosmic Time

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Contributing teams: The CANDELS Collaboration

In the local universe, Ultraluminous Infrared Galaxies (ULIRGs, L_IR>10^12 L_sun) are all interacting and merging systems. To date, studies of ULIRGs at high redshift have found a variety of results due to their varying selection effects and small sample sizes. Some studies have found that mergers still dominate the galaxy morphology while others have found a high fraction of morphologically normal or clumpy star forming disks. Near-infrared imaging is crucial for interpreting galaxy structure at high redshift since it probes the rest frame optical light of a galaxy and thus we can compare directly to studies in the local universe. We explore the evolution of the morphological properties of (U)LIRGs over cosmic time using a large sample of galaxies from Herschel observations of the CANDELS fields (including GOODS, COSMOS, and UDS). In particular, we investigate whether the role of galaxy mergers has changed between z~2 and now using the extensive visual classification catalogs produced by the CANDELS team. The combination of a selection from Herschel, near the peak of IR emission, and rest-frame optical morphologies from CANDELS, provides the ideal comparison to nearby (U)LIRGs. We then study the how role of galaxy mergers and the presence of AGN activity correspond to the galaxy's position in the star formation rate - stellar mass plane.

324.07D – Photometric Study of Massive Evolved Galaxies in the CANDELS GOODS-S at z>3

Hooshang Nayyeri[1], Bahram Mobasher[1], Henry C. Ferguson[2], Tommy Wiklind[2], Shoubaneh Hemmati[1], Stephane De Barros[1], Adriano Fontana[3], Tomas Dahlen[2], Anton M. Koekemoer[2]
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United States. 3. INAF, Rome, Italy.

According to the hierarchical models, galaxies assemble their mass through time with the most massive and evolved systems found in the more recent times and in the most massive dark matter halos. Understanding the evolution of mass assembly with cosmic time plays a central role in observational astronomy. Here, we use the very deep near Infra-red HST/WFC3 observations by the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS) to study passively evolving, old and massive systems at high redshifts. For this we utilize the pronounced Balmer Break (an age dependent diagnostic at rest-frame 3648Å) in post-starburst galaxies to devise a Balmer Break Galaxy (BBG) selection. We use the CANDELS WFC3 1.6 μm selected catalog in the GOODS-S, generated with TFIT algorithm suitable for mixed resolution data sets, to select the candidates. We identified 24 sources as candidates for evolved systems in the redshift 3.5<z<4.0. Simulations and also model color tracks of galaxies show that the most noticeable source of contamination is from dusty starburst galaxies that can produce similar red colors. Fitting the spectral energy distribution (SED) of the candidate galaxies with a well-constructed library of model galaxies show that the candidate galaxies have estimated ages older than 100 Myr and masses larger than 10^{10} M_Sun consistent with being old and massive systems. Forty percent of the passive candidates are also selected by the LBG selection indicating presence of residual star formation in the post-starburst population. Given the age and the current redshift, some of these systems must have formed bulk of their mass only a few hundred million years after the Big Bang.

325 – Exoplanet Models
Oral Session – Potomac Ballroom D – 08 Jan 2014 02:00 pm to 03:30 pm

325.01 – Remastering the RV Classics: Self-Consistent Dynamical Models for the 55 Cnc and GJ 876 Planetary Systems

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1. Pennsylvania State University, State College, PA, United States. 2. University of Florida, Gainesville, FL, United States. 3. Yale, New Haven, CT, United States.

Over the past two decades, radial velocity (RV) observations have uncovered a handful of dynamically rich exoplanet systems. In particular, the 55 Cnc and GJ 876 systems have 4+ planets with some of them displaying planet-planet interactions on the observing timescale. In turn, this makes the posterior distributions of these systems oddly shaped and extremely difficult to sample from, especially when employing a Newtonian model. We apply our Radial velocity Using N-body Differential evolution Markov chain Monte Carlo code (RUN DMC; Nelson et al. 2013, submitted) to these two landmark systems. For 55 Cnc, we investigate the orbital architecture based on a cumulative 1418 RV observations from various sources and transit constraints from Winn et al. 2011. We find planets "b" and "c" are apsidally aligned but not in a mean-motion resonance, and the orbital stability of the system is sensitive to the orbital properties of planet "f". For GJ 876, we analyze the Keck HIRES (Rivera et al. 2010) and HARPS (Correia et al. 2010) data to constrain the distribution of the Laplace argument and mutual inclinations amongst planet pairs based on both the RVs and assumption of long-term stability.

325.02 – Finding the Needle in the Haystack: A High-Fidelity Model of the Solar System for Simulating Exoplanet Observations

Ashlee N. Wilkins[1,2], Aki Roberge[2], Maxime Rizzo[1,2], Erika Nesvold[3,2], Christopher C. Stark[2], Michael W. McElwain[2], Marc J. Kuchner[2], Tyler D. Robinson[4], Victoria Meadows[4], Amber Straughn[2], Margaret C. Turnbull[5]
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As the possibility of discovering characterizable, habitable, Earth-like planets around Sun-like stars improves, the need for accurate model representations of such systems becomes ever more pressing. The signals of habitability will be buried within spectral information like needles in haystacks, so we present a complete model of the Solar System we call ``Haystacks'' that can be readily placed at various distances and inclinations to simulate an exoplanetary system with a known habitable planet. The Haystacks data product is a three-dimensional spectral cube. The spatial x-y plane spans 150 AU in both directions, centered on the Sun. The spectral z-dimension is divided into four hundred slices ranging from 0.3μm to 2.5μm, evenly spaced in wavelength, yielding R~200 in the V-band. In the model, we include the Solar System planets, inner (exo)zodiacal dust, outer Kuiper Belt dust, and extragalactic background, all sourced from a combination of observations and models. This makes the Haystacks model the most comprehensive, robust, and detailed model available for prediction of noise levels, confusion, and the ability to measure biomarkers in a directly observed system. The final data cubes are available for download by the public. Any user who accesses our NASA-hosted webpage simply inputs a distance and an inclination, and they are provided with the corresponding spectral cube. We demonstrate the power of such data cubes with several simulations of observations with various telescopes and instruments, and present preliminary results on detectability and necessary instrument/telescope capabilities.

325.03 – Transiting Exoplanet Simulations with the James Webb Space Telescope

Natasha Batalha[1,3], Jason S. Kalirai[1], Jonathan I. Lunine[2], Avi Mandell[4]
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The James Webb Space Telescope (JWST) was ranked as the top science priority in the 2000 Astronomy & Astrophysics Decadal Survey. We assess the potential for JWST to characterize the atmospheres of super-Earth exoplanets, by simulating a range of transiting spectra with different masses and temperatures. Our results are based on a JWST simulator tuned to the expected performance of the spectroscopic instruments NIRSpec and NIRISS, and is based on the latest exoplanet transit models. This study is especially timely since the observing modes for the science instruments on JWST are finalized and because NASA has selected the TESS mission as an upcoming Explorer.

325.04 – Just How Earth-like are Extrasolar Super-Earths? Constraints on H+He

Envelope Fractions from Kepler's Planet Candidates

Angie Wolfgang[1], Eric Lopez[1]
1. University of California, Santa Cruz, Santa Cruz, CA, United States.
Contributing teams: Kepler Team, SAMSI Bayesian Characterization of Exoplanet Populations Working Group

With 3500 planetary candidates discovered in its first 3 years of data, the Kepler Mission promises to answer one of the most fundamental questions posed in exoplanetary research: what kinds of planets occur most often in our Galaxy? As Kepler primarily yields planetary radii and orbital periods, it has enabled numerous studies of the occurrence rate of planets as a function of these variables. Unfortunately, the full mass distribution, and thus a direct measure of these planets' possible compositions, remains elusive due to the unsuitability of these faint targets for radial velocity follow-up and the relative rareness of transit timing variations. We show, however, that relatively straightforward models of planetary evolution in an irradiated environment can make some progress without this full mass distribution towards understanding bulk compositions of the abundant Super-Earth/Sub-Neptunes that Kepler has discovered. In particular, we constrain the distribution of envelope fractions, i.e. the fraction of a planet's mass that is in a gaseous hydrogen and helium envelope around its rocky core, for this exoplanet population that has no analogs in our Solar System. This research builds on collaborations between astronomers and statisticians forged during a three week workshop on "Modern Statistical and Computational Methods for Analysis of Kepler Data" at SAMSI in June 2013.

325.05 – Habitable Evaporated Cores: Converting Mini-Neptunes into Super-Earths in the Habitable Zone of M Dwarfs

Rodrigo Luger[1,2], Rory Barnes[1,2], Eric Lopez[3], Jonathan J. Fortney[3,2], Brian K. Jackson[4], Victoria Meadows[1,2]
1. Astronomy Department, University of Washington, Seattle, WA, United States. 2. Virtual Planet Laboratory, Seattle, WA, United States. 3. Department of Astronomy and Astrophysics, University of California, Santa Cruz, CA, United States. 4. Carnegie Department of Terrestrial Magnetism, Washington, DC, United States.

We show that photoevaporation and Roche lobe overflow of small gaseous exoplanets ("mini-Neptunes") in the habitable zone (HZ) of young late M dwarfs can remove several Earth masses of hydrogen/helium from these planets and transform them into potentially habitable worlds, which we call "habitable evaporated cores." We couple a simple model for the evolution of inflated planets that are partly overflowing their Roche lobes with evaporation due to strong extreme ultraviolet (XUV) irradiation. We also couple the orbital effects of anisotropic mass loss with tidal evolution and show that this coupling can lead to unexpected behavior, such as a net increase of the eccentricity and an outward-then-inward evolution of the semi-major axis, significantly enhancing the mass loss rate. Habitable evaporated cores are most likely to form from planets with up to about 40% gas by mass orbiting M4 stars and later. As terrestrial planet formation by accumulation of local material is likely to form sub-Earth mass planets, evaporation of mini-Neptunes could be the dominant formation mechanism for volatile-rich super-Earths around M dwarfs. Such habitable evaporated cores are likely to be detected in upcoming surveys.

325.06 – Detectable Spectral Fingerprints of Super- and Mini-Earths in the HZ

Sarah Rugheimer[1], Lisa Kaltenegger[1,2], Dimitar D. Sasselov[1]
1. Harvard University - CFA, Cambridge, MA, United States. 2. MPIA, Heidelberg, Germany.

A wide range of potentially rocky transiting planets in the habitable zone (HZ) have been detected by Kepler as well as ground-based searches, some smaller and some bigger than Earth. The inferred mass, surface pressure (scaled with gravity in first order), and location in the HZ changes the observable spectrum of such exoplanets - was well as our ability to detect those signatures remotely with future space and ground-based missions like JWST, GMT and E-ELT, including biosignatures that can indicate habitable conditions. We explore Mini- and Super-Earths in the HZ and Earth-like planets at different epochs around various stellar types using a 1D climate and photochemistry model with a line-by-line radiative transfer code to model the atmosphere and detectable spectral features of such potentially habitable exoplanets.

325.07 – Water Cycling Between Ocean and Mantle: Super-Earths Need Not be Waterworlds

Nicolas B. Cowan[1], Dorian S. Abbot[2]
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Large terrestrial planets are expected to have muted topography and deep oceans, implying they should be entirely covered in water, so-called waterworlds. Quantitatively, a planet ten times the mass of Earth is not expected to have exposed

continents unless it has a water mass fraction less than 3×10^{-5}, roughly ten times drier than Earth. This is important because waterworlds lack a silicate weathering thermostat so their climate is predicted to be less stable than that of planets with exposed continents. Water is partitioned, however, between a surface reservoir, the ocean, and an interior reservoir, the mantle. Plate tectonics transports water between these reservoirs on geological timescales. Degassing of melt at mid-ocean ridges and serpentinization of oceanic crust are mediated by sea-floor pressure, providing a stabilizing feedback on long-term ocean volume. Motivated by Earth's approximately steady-state deep water cycle, we develop a two-box model of the hydrosphere and derive steady-state solutions to the water-partitioning on terrestrial planets. Since hydrostatic pressure is proportional to gravity, super-Earths with a deep water cycle will tend to store most of their water in the mantle. We conclude that tectonically active terrestrial planets with H_2O mass fractions less than 3×10^{-3} will have both oceans and exposed continents. The circumstellar habitable zone is therefore equally wide for any tectonically active planet.

325.08 – Effects of Extreme Obliquity Change on the Habitability of Extrasolar Planets

John C. Armstrong[1], Rory Barnes[2], Shawn Domagal-Goldman[3]
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Contributing teams: Virtual Planetary Laboratory

We explore the impact of obliquity variations on planetary habitability in hypothetical systems with high mutual inclination and demonstrate that the system architecture can dramatically affect the limits of the habitable zone. We restrict our exploration to hypothetical systems consisting of a solar-mass star, an Earth-mass planet at 1 AU, and 1 or 2 giant planets. We verify that these systems are stable for 100 million years with N-body simulations, and calculate the obliquity variations induced by the orbital evolution of the Earth-mass planet. Next, we run a simplified energy balance model on the terrestrial planet to assess surface temperature and ice coverage on the planet's surface. Finally, we explore differences in the outer edge of the habitable zone for planets with rapid obliquity variations. We run climate simulations for a range of values for the semi-major axis, assuming that the obliquity variations of the nominal system (terrestrial planet at 1 AU) are typical for each orbital architecture. We find that planets undergoing extreme axial perturbations may be habitable at distances up to 93 % larger than our Earth standard model. Additionally, up to 100 % of this enhancement can be traced to the variability in the orbital properties. This extension arises because the obliquity variations suppress the build-up of ice sheets at the poles, reducing the effectiveness of the ice-albedo feedback.

326 – Extrasolar Planet Detection - Optical RV Surveys

Oral Session – Maryland Ballroom A – 08 Jan 2014 02:00 pm to 03:30 pm

326.01 – Correcting Astrophysical Noise in HARPS-N RV Measurements

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Contributing teams: the HARPS-N Collaboration

Radial velocity instrumental precision has improved to the degree that measurements are now limited in part by the noise intrinsic to the host star, or stellar 'jitter'. Several different phenomena contribute to the observed jitter, including pressure waves, granulation, magnetic features caused by stellar activity, and solar-like magnetic cycles. The amplitude of these effects ranges from 10 to 400 cm/s, depending on stellar type, and pose a significant limitation to detecting Earth analogues. We carry out a survey of bright, quiet stars with the new HARPS-N instrument, an ultra-stabilized R=115,000 cross-dispersed spectrograph located on the 3.6m Telescopio Nazionale Galileo on the island of La Palma. We look for correlations between these radial velocity measurements and known activity indicators, including line bisector measurements and the CaII index. We also investigate the correlation between radial velocity measurements and variations in line depth ratios, which may be sensitive to temperature variations as small as 5K. By correcting for these combined effects, we can improve the radial velocity precision, enabling the detection of low-mass planets.

326.02 – The Solar Twin Planet Search

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We present preliminary results from an ongoing radial velocity planet search around solar twins using the HARPS spectrograph. By limiting our sample to stars with Teff +/- 100 K, log(g) +/- 0.1 dex, and [Fe/H] +/- 0.1 dex of the solar values, we can obtain stellar elemental abundances [X/Fe] to a precision of 0.01 dex (Melendez et al. 2009). Our study is leveraging this unprecedented level of precision and the sensitivity of the HARPS instrument to investigate the connection between planet occurrence and stellar abundances at a new level of detail.

326.03 – Early Doppler Performance from New Generation High Resolution Optical and near Infrared Planet-hunting Spectrographs

Jian Ge[1], Frank Varosi[1], Scott Powell[1], Bo Zhao[1], Sidney Schofield[1], Jian Liu[1], Craig Warner[1], Sirinrat Sithajan[1], Rui Li[1], Matthew W. Muterspaugh[2], Michael W. Williamson[2], Louis Avner[1], Hali Jakeman[1]
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The next generation of radial velocity (RV) planet surveys require high precision (sub m/s for optical and 1-3 m/s for near infrared (NIR)) and high cadence (~100 RV measurements per star) to systematically reach low mass planet populations, including habitable Earth-like planets, around FGKM dwarfs and study their properties. These require new sensitive optical and NIR high resolution spectrographs. At UF, we have developed two new generation optical and NIR high resolution spectrographs for high precision RV low mass planet surveys. The optical high resolution spectrograph called EXtremely high Precision ExtrasolaR planet Tracker (EXPERT) III (EXPERT-III), was commissioned at the Automatic Spectroscopic Telescope (AST), a robotic telescope at Fairborn Observatory in Arizona in July 2013 and has produced a spectral resolution of about 100,000 and a simultaneous wavelength coverage of 0.38-0.9 mm with a 4kx4k back-illuminated Fairchild CCD detector. The early RV measurements show that this instrument has reached ~0.7 m/s RV precision and daily instrument stability is better than 5m/s. The near IR spectrograph, called the Florida IR Silicon immersion grating spectromeTer (FIRST), has produced R~60,000 at 0.8-1.8 microns with a 2kx2k H2RG IR array. FIRST is the first high resolution NIR spectrograph taking full advantage of an innovative silicon immersion grating to achieve high spectral resolution (3.4 times higher than a commercially available echelle grating of the equal size and blaze angle) in an extremely compact design. FIRST is schedule to be commissioned at AST in October 2013. Here we report on-sky RV performance and early science results from the AST robotic observations.

326.04 – Survey of Close-in Super-Earths Using a New Generation Optical High Resolution Spectrograph

Sirinrat Sithajan[1], Jian Ge[1], Matthew W. Muterspaugh[2], Frank Varosi[1], Rui Li[1], Bo Ma[1], Neil B. Thomas[1], Ji Wang[3], Rory Barnes[4], Ted Maxwell[2]

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A number of planets discovered using various ground-based and space-based surveys have allowed us to begin to study their statistical properties and find clues for their formation mechanisms. However, due to the traditionally adopted survey strategy, which is to observe stars with variable observational cadences ("run and gun" style), of high precision radial velocity (RV) surveys, the resulting survey completeness is usually low, especially at the low mass regime. This prevents us from obtaining critical data needed to investigate the statistical properties and formation mechanisms of low mass planet populations. We have designed a deep and homogeneous RV survey of ~500 nearby bright FGKM dwarfs for detecting low mass planets in 2014-2017 with a totally different survey strategy and cadence. This survey will observe every selected (bright, inactive, F5V to M4V) star ~100 times randomly spread over 300 days using our new generation extremely high Doppler precision optical spectrograph, called EXtremely high Precision ExtrasolaR planet Tracker III (EXPERT-III) (~1 m/s precision), at the Automatic Spectroscopic Telescope (AST), a 2-m robotic telescope at Fairborn Observatory in Arizona. The flexible queue schedule offered by this robotic telescope greatly facilitates this high precision and high cadence survey. We have demonstrated the survey performance and predicted results through simulations. They show that an unprecedented high completeness sample of close-in super-Earths can be achieved. Therefore, this survey will not only precisely measure statistical properties of the close-in super Earth population largely uncovered by the Kepler mission, but also offer a uniquely homogeneous sample to constrain various planet formation models. Furthermore, this survey has a great sensitivity to probe super-Earth planets in habitable zones around K and M dwarfs.

326.05 – Early Giant Planet Candidates from the SDSS-III MARVELS Planet Survey

Neil Thomas[1], Jian Ge[1], Rui Li[1], Sirinrat Sithajan[1], Yunmei Chen[1], Jiangli Shi[1], Bo Ma[1], Jian Liu[1]
1. University of Florida, Gainesville, FL, United States.

We report the first discoveries of giant planet candidates from the SDSS-III MARVELS survey. These candidates are found using the new MARVELS data pipeline developed at UF from scratch over the past two years. Unlike the old data pipeline, this pipeline carefully corrects most of the instrument effects (such as trace, slant, distortion, drifts and dispersion) and observation condition effects (such as illumination profile). The result is long-term RV precisions that approach the photon limits in many cases and has yielded four giant planet candidates of ~1-6 Jupiter mass from only the initial fraction of data processed with the new techniques. More survey data is being processed which will likely lead to discoveries of additional giant planet candidates that will be verified and characterized with follow-up observations by the MARVELS team. The MARVELS survey has produced the largest homogeneous RV measurements of 3300 V=7.6-12 FGK stars with well defined cadence (~27 RV measurements over 2 years). The MARVELS RV data and other follow-up data (photometry, high contrast imaging, high resolution spectroscopy and RV measurements) will explore the diversity of giant planet companion formation and evolution around stars with a broad range in metallicity ([Fe/H]~-1.5-0.5), mass (M~0.6-2.5M(sun)), and environment (thin disk and thick disk), and will help to address the key scientific questions identified for the MARVELS survey including, but not limited to: Do metal poor stars obey the same trends for planet occurrence as metal rich stars? What is the distribution of giant planets around intermediate-mass stars and binaries? Is the "planet desert" within 0.6 AU in the planet orbital distribution of intermediate-mass stars real?

327 – From Protostars to Lensed Galaxies: The Immense Riches from Herschel

Special Session – Maryland Ballroom C – 08 Jan 2014 02:00 pm to 03:30 pm

The 3.5-m Herschel Space Telescope has pioneered the deepest explorations of the infrared/sub-mm wavelength regime to date. Although it exhausted its cryogen in April 2013, new results will continue to pour out from Herschel for many years to come. These include science done by astronomers with targeted programs, as well as from users of the huge Herschel Science Archive compiled from over four years of observations. This Special Session begins close by, with studies of the earliest signs of star-birth in the Galaxy, and rapidly expands out to include galaxies near and far. The topics are chosen to emphasize the remarkable power of Herschel at mapping gas and dust in nearby galaxies in great detail, as well as the probing of very distant dusty galaxies amplified by gravitational lenses. The talks will span from the heating and cooling of diffuse and dense gas in nearby galaxies, to feedback from starburst and active galactic nuclei (AGN) over cosmic time. The speakers are members of Herschel Key Programs, which collectively used 50% of all Herschel time. An important goal of the Session is to emphasize the incredible richness of the Herschel archive, to allow synergy with other facilities (Planck, CCAT, ALMA, SOFIA, JWST, SPICA), and to help provide a springboard to foster potentially new research programs at other wavelengths.

327.01 – From Protostars to Lensed Galaxies: The Immense Riches from Herschel

George Helou[1], Göran L. Pilbratt[2]
1. Caltech, Pasadena, CA, United States. 2. ESTEC, ESA, Noordwijk, Netherlands.

On 29 April 2013, the Herschel Space Observatory used the last of its liquid Helium, concluding a very successful cryogenic mission and ushering in the "post-operational phase" of science exploitation. Published results already span all major areas of astrophysics, and many more results are waiting to be mined out of the all-public Herschel Science Archive. Resources available to support this mining will be at the community's disposal for a few more years, but the synergies between Herschel data and Spitzer, WISE, SOFIA, and eventually JWST data will keep the archive busy for a much longer time.

327.02 – Unraveling the Evolution of Protostars in Diverse Environments: The Herschel Orion Protostar Survey

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Contributing teams: and the Herschel Orion Protostar Survey Team

The Herschel Orion Protostar Survey (HOPS), a 200 hour PACS imaging and spectroscopy OTKP, is the cornerstone of a large multi-observatory campaign combining Herschel data with observations from Spitzer,Hubble, APEX, and other facilities. HOPS has produced well sampled 1–870 micron SEDs of over 300 protostars in the Orion molecular clouds, the most extensive such survey of a single cloud complex to date, and has obtained PACS spectra of 36 protostars to observe line emission from CO, OH, and H2O. We will present the major HOPS discoveries that demonstrate Herschel's contributions to an emerging picture of protostellar evolution within the diverse environments of the Orion A & B molecular clouds. Among these, the HOPS team has discovered protostars undetected by Spitzer that appear to be the youngest protostars in Orion (Stutz et al. 2013). We have found that the luminosities of high-J CO lines are correlated with protostellar luminosities, but the excitation temperatures are not, indicating that these lines form in high-temperature gas within outflows (Manoj et al. 2013). We have also constructed and modeled the first 1–70 um SED of a protostellar FU Ori object before and after its outburst, finding an atypically low post-outburst luminosity (Fischer et al. 2012). Finally, we have identified systematic variations in the spacing and luminosity of protostars between the different environments found in Orion (Megeath, Stanke, in prep.). More generally, the HOPS team is now determining the fundamental protostellar properties (envelope mass and density, system luminosity, and outflow cavity geometry) of the 300 Orion protostars by a comparison of the SEDs to radiative transfer models. We will summarize the prospects of using these fundamental properties to construct a detailed sequence for the physical evolution of protostars as they dissipate their envelopes, accounting for the influence of the diverse environments found within Orion.

327.03 – Herschel's Unique View of Nearby Galaxies

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Contributing teams: KINGFISH Team

By targeting the far-infrared and sub-millimeter regime with unprecedented sensitivity and angular resolution, the Herschel Space Telescope has provided new insights into both the phenomenology and the physics of dust emission from galaxies. I review the results obtained so far by KINGFISH (Key Insights on Nearby Galaxies: a Far-Infrared Survey with Herschel), an Herschel Open Time Key Project, and by similar projects on galaxies within the local ~30 Mpc, where Herchel affords a spatial resolution better than ~ 0.8-5 kpc, and can thus probe the variety of environments within galaxies.

327.04 – Observations of Luminous Infrared Galaxies with Herschel

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A major result of the IRAS survey was the discovery of a large population of luminous infrared galaxies (LIRGs) which emit a significant fraction of their bolometric luminosity in the far-infrared. LIRGs cover the full range of morphologies from isolated disk galaxies, to advanced mergers, exhibiting enhanced star-formation rates and a higher fraction of Active Galactic Nuclei (AGN) compared to less luminous galaxies. A detailed study of low-redshift LIRGs is critical for our understanding of the cosmic evolution of galaxies and black holes, since LIRGs comprise the bulk of the cosmic far-infrared background and dominate the star-formation between $0.5 < z < 1$. With ISO, it was possible to measure the full suite of infrared diagnostic lines in local normal and luminous infrared galaxies for the first time, but samples were small and observations challenging. With Herschel, we have been able to study large samples of low-redshift LIRGs, and even probe the physical conditions in poweful starburst galaxies out to significant redshifts. By combining the Herschel data with those from Spitzer, it is now possible to understand the heating and cooling of the dust and gas in complete samples of LIRGs for the first time. I will review recent results from a number of GTO, OTKP and GO programs in an attempt to summarize the advances we have made in understanding star formation and black hole accretion in LIRGs as a direct result of the Herschel mission.

327.05 – Herschel's Far-Infrared View of Galaxy Formation and Evolution

James Bock[1, 2]

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Herschel opened a new window on galaxy formation at far-infrared and sub-millimeter wavelengths, providing imaging in 6 spectral bands ranging from 70 - 500 um, diffraction-limited spatial resolution, and surveys ranging from deep well-studied fields to scanned maps covering large areas of sky. Herschel shows rapidly evolving far-infrared galaxy populations, with emission largely driven by dust-obscured star-formation. Herschel survey data mapped out the detailed evolution of the far-infrared luminosity function from our local universe to moderate redshifts. Combined with multi-wavelength surveys, we determined the role of far-infrared emission in diverse galaxy populations, including AGNs, as well as dust-obscured, Lyman-break, and radio galaxies. Herschel images provide a ready means to identify gravitationally lensed systems, expanding on the total number of known lenses, and providing spectacular high-redshift galaxies for detailed study. Observations of rich cluster fields produced new measurements on lensed galaxies, the extragalactic background, and the SZ effect. The analysis of Herschel images pioneered new statistical techniques to probe galaxies below the confusion limit, stacking on known populations to derive ensemble properties, and mapping large-scale structure through power spectral methods to explore the relationship between galaxy formation and the underlying distribution of dark matter. I will present recent results from Herschel extragalactic science observations, concentrating on the Herschel Multi-Tiered Extragalactic Survey (HerMES), with selected highlights from all surveys.

328 – Galaxies II - Starbursts
Oral Session – Potomac Ballroom C – 08 Jan 2014 02:00 pm to 03:30 pm

328.01 – Atomic Gas Distribution in HCG31 and HCG92

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We present Green Bank Telescope (GBT) 5x5 grid observations surrounding the actively star forming groups Hickson Compact Group, HCG 31 and HCG 92. We find that the total HI content of the groups are 2x10^10 and 2.5x10^10 solar masses respectively. The HI in HCG31 is mostly associated with the central region, however, there is a faint extension of the order of 10^9 solar masses of gas toward the southeast direction detected at the GBT pointing centered at a distance of 185 kpc from the group center. The velocity range of the HI is similar to the HI in the central pixel indicating its kinematic link to the gas in the center of the group. HCG 92 shows strong HI emission at a position of a pointing 4' offset from the center. The ``HI-wing" at velocities 6350-6500 km/s (Borthakur et al. 2010) were found to be confined to a few pointings adjacent to the peak suggesting that the wing as is localized and not extended. However, this must be gas stripped due to interactions and are dynamically connected to the Arc-N (Williams et al. 2002). We comment on the survival of the gas from the ionizing photons of the metagalactic ultraviolet background and those produced by the starburst. The implication of the existence of an HI rich environments surrounding the starbursts support the possibility of continued and future star formation in these groups.

328.02 – Do Lyman-alpha photons escape from star-forming galaxies through dust holes?

Kevin France[1], Aida Wofford[2], Claus Leitherer[3], Brian Fleming[4, 1], Stephan R. McCandliss[4], Nicholas Nell[1]
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H I Lyman-alpha (LyA) is commonly used as a signpost for the entire galaxy at redshifts z>2, and yet spatially and kinematically resolved views of the local conditions within galaxies that determine the integrated properties of this line are scarce. We obtained Hubble Space Telescope (HST) images in continuum-subtracted LyA, H-alpha, H-beta, and far-UV continuum of three low-inclination spiral star-forming galaxies located at redshifts z=0.02, 0.03, and 0.05. This was accomplished using the UVIS and SBC channels of the Wide Field Camera 3 (WFC3) and the Advanced Camera for Surveys (ACS), respectively. Previous HST spectroscopy obtained by our team with the Cosmic Origins Spectrograph (COS) showed that the galaxies display different integrated LyA profiles within their central few kiloparsecs, i.e., pure absorption, single emission, and double emission, which are representative of what is observed between redshifts 0-3. This data is useful for establishing the relative importance of starburst phase, dust content, and gas kinematics in determining the LyA escape. We present preliminary results that combine our spectroscopic and imaging observations.

328.03D – Neutral Gas and Low-Redshift Starbursts: From Infall to Ionization

Anne Jaskot[1], M. S. Oey[1], John J. Salzer[2], Angela Van Sistine[2], Martha P. Haynes[3]
1. University of Michigan, Ann Arbor, MI, United States. 2. Indiana University, Bloomington, IN, United States. 3. Cornell University, Ithaca, NY, United States.

The interplay of gas inflows, star formation, and feedback drives galaxy evolution, and starburst galaxies provide important laboratories for probing these processes at their most extreme. With two samples of low-redshift starburst galaxies, we examine the conversion of neutral gas into stars and the subsequent effects of stellar feedback on the neutral interstellar medium (ISM). The ALFALFA Hα survey represents a complete, volume-limited sample of HI-selected galaxies with 21 cm spectra and Hα and R-band imaging. By contrasting the starburst galaxies with the rest of the gas-rich galaxy population, we investigate the roles of galaxy morphology, HI kinematics, and the atomic gas supply in triggering extreme levels of star formation. Both an elevated HI gas supply and an external disturbance are necessary to drive the starbursts. While neutral gas may fuel a starburst, it may also increase starbursts' optical depths and hinder the transport of ionizing radiation. In contrast to the expectations for high-redshift star-forming galaxies, neutral gas appears to effectively bar the escape of ionizing radiation in most low-redshift starbursts. To evaluate the impact of radiative feedback in extreme starbursts, we analyze optical spectra of the Green Pea galaxies, a low-redshift sample selected by their intense [O III] λ5007 emission and compact sizes. We use nebular photoionization and stellar population models to constrain the Peas' burst ages, ionizing sources, and optical depths and find that the Peas are likely optically thin to Lyman continuum (LyC) radiation. These young starbursts still generate substantial ionizing radiation, while recent supernovae may have carved holes in the ISM that enhance LyC photon escape into the intergalactic medium. While the ALFALFA survey demonstrates the role of external

processes in triggering starbursts, the Green Peas show that starbursts' radiation can escape to affect their external environment.

328.04 – Discovery of GeV Gamma-ray Emission from the Circinus Galaxy with the Fermi-LAT

Grzegorz M. Madejski[1], Masaaki Hayashida[2, 1], Lukasz Stawarz[5], Chi C. Cheung[4], Keith Bechtol[3, 1]
1. Stanford Linear Accelerator Ctr / KIPAC., Menlo Park, CA, United States. 2. Institute for Cosmic Ray Research / Univ. of Tokyo, Kashiwa City, Chiba, Japan. 3. Naval Research Lab, Washington, DC, United States. 4. KITP, Univ. of Chicago, Chicago, IL, United States. 5. ISAS / JAXA, Tokyo, Japan. Contributing teams: On Behalf of the Fermi - LAT Team

Here, we report the detection of gamma-ray emission from the Circinus Galaxy with the Large Area Telescope onboard the Fermi Gamma-ray Space Telescope. Circinus is a starburst galaxy with a heavily obscured active nucleus, located at the distance of about 4 Mpc. The 0.1-100 GeV gamma-ray spectrum is well-described as a power law with photon index 2.2, with no indication of variability. However, with an observed flux of 2 x 10e-8 photons/cm^2/s, its ratios of gamma-ray to radio, as well as gamma-ray to IR fluxes are significantly higher (by a factor of a few) than in starburst galaxies detected so far with Fermi. We conclude that the observed gamma-ray flux is higher than that expected from interactions of cosmic rays with the interstellar medium of the galaxy, and/or the inverse Compton radiation from the radio-emitting regions, leaving the origin of gamma-rays from Circinus uncertain.

328.05D – A Survey of the Cool Molecular ISM Properties of Nearby Galaxies using the Herschel FTS

Julia R. Kamenetzky[1]
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The lowest-energy rotational lines of CO are well-known to trace cool, star-forming molecular gas. The Herschel SPIRE Fourier Transform Spectrometer (FTS) observed, for the first time, CO's higher-energy J=4-3 to J=13-12 lines in nearby galaxies. The higher-J lines are more luminous than expected and arise from a warmer, diffuse component of molecular gas. Because such gas dominates the total energy output of CO, it is key to studying ongoing questions of feedback interactions between the ISM, star formation, and AGN. Here we present a uniquely comprehensive survey of the molecular gas/dust of nearby galaxies observed with the FTS, complemented by low-J CO and photometric data. Full results are presented for twenty well-known galaxies as well as some preliminary results for all three hundred FTS galaxies, utilizing a consistent correction for source-beam coupling. Via radiative transfer modeling of CO (pressure and mass), the warm and cool components of CO gas are simultaneously modeled and compared by galaxy type, luminosity, and (specific) star formation rate. This work demonstrates that simultaneous modeling is necessary; low-J lines alone overestimate gas pressure (but consistently determine cold CO mass). We also sought to determine the diagnostic power of an individual high-J line for future galaxy observations for which few CO lines are available; the J=6-5 line, observable with ALMA, is a useful proxy for the warm gas luminosity and mass. Special emphasis is placed on M82 and our finding, consistent with an emerging picture among other galaxies, that high-J CO excitation cannot be explained by photon-dominated regions (PDRs), as low-J excitation can in this galaxy. Instead, mechanical/turbulent heating must play a role. We also discuss atomic fine structure lines ([CI], [CII], [NII]), dust properties, and comparisons to high-z submillimeter galaxies. Finally, we apply the same techniques to the newly discovered rotational CO emission in the debris of SN1987A, revealing more CO mass than previously detected. Because nearby galaxies can be studied in greater detail, characterizing their molecular gas properties is necessary to understand the growing population of distant submillimeter galaxies.

329 – Galaxies III - Andromeda and Nearby Disks
Oral Session – National Harbor 3 – 08 Jan 2014 02:00 pm to 03:30 pm

329.01D – Understanding the Structure and Evolution of Nearby Disk Galaxies

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In order to understand the structure and evolution of disk galaxies, we studied the stellar and gaseous components as well as the star formation rate in nearby disk galaxies. We used PS1 medium deep survey images to derive five-band (grizy) surface brightness profiles down to 30 ABmag/arcsec^2 for about 700 galaxies. From these stellar mass and mass-to-light ratio radial profiles are derived. The stellar mass radial profiles tend to bend-up at large radii, this often traces an extended old stellar population. The mass-to-light ratio profiles tend to rise outside the r25 radii. We also find a larger fraction of up-bending surface brightness profiles than Polen & Trujillo (2006). This may be because their sample is biased towards low surface brightness galaxies. We used HIPASS data as well as VLA HI 21cm data to study the gas component and dynamics of disk galaxies. We used the GALEX UV images to study the star formation of a HI-selected star-forming sample of about 400 galaxies, compiling a database of FUV and NUV radial profiles and related parameters. We used this to study the star forming efficiency (SFE, star formation rate per unit area divided by gas surface mass density) of the sample galaxies. We found that the UV based SFE has a tighter relationship with HI mass than an H_alpha based SFE as typically used in previous studies and the UV SFE is flat across wide range of stellar mass. We constructed a simple model to predict the distribution of interstellar medium and star formation rate in an equilibrium disk with constant two-fluid Toomre Q. This model can reproduces the SFE relations we derived.

329.02D – The Survey of Lines in M31 (SLIM): Origin of [CII] Emission

Maria Kapala[1], Karin Sandstrom[1, 2], Brent Groves[1], Kevin V. Croxall[3], Julianne Dalcanton[4], Karl D. Gordon[5], Oliver Krause[1], Kathryn Kreckel[1], Adam K. Leroy[6], Hans-Walter Rix[1], Eva Schinnerer[1], Fabian Walter[1]
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The [CII] 158 micron line is typically the brightest far-IR emission line from star-forming galaxies. To use this line as a tracer of star-formation and a diagnostic of ISM conditions, we must understand which phases of the ISM and what gas heating sources are contributing to it. As a massive, nearby galaxy, Andromeda is ideal for studying [CII] because we can resolve individual star-forming regions in the galaxy, but it is representative of more distant galaxies. To address the origins of [CII], we have assembled a unique set of observations including: [CII] 158 micron and [OI] 63 micron lines from Herschel PACS; fully sampled optical integral field spectroscopy from PPAK on the Calar Alto 3.5m, and Herschel dust continuum mapping from 70-500 microns. These observations span a range of conditions across Andromeda. We present first results on how [CII] correlates with the far-IR continuum on ~50 pc scales. In particular, we find that star-forming regions in M31 do not exhibit a "[CII] line deficit" even in regions where the dust is very warm. Using the optical line emission, we determine the fraction of [CII] emission spatially associated with star-forming regions. Our method implies a high fraction ~40-75% of [CII] emission is coming from diffuse regions. These diffuse regions appear to dominated by the UV interstellar radiation field, which we infer from the Pan-Chromatic Hubble Andromeda Treasury data to be dominated by B stars. Our results suggest that studies using [CII] to trace the massive star-formation rate must take into account the the contribution of older stellar populations in heating the ISM gas.

329.03D – Life in the Outer Limits: Insight into Hierarchical Merging from the Outermost Structure of the Andromeda Stellar Halo

Rachael Beaton[1], Steven R. Majewski[1], Richard J. Patterson[1], Puragra Guhathakurta[2], Karoline Gilbert[3], Jason S. Kalirai[3], Erik J. Tollerud[4]
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Contributing teams: SPLASH Team

Owing to their large dynamical timescales, the stellar haloes of Milky Way (MW) sized galaxies represent ideal environments to test modern theories of galaxy formation in the Lambda-CDM paradigm. Only in stellar haloes can the remnants of hierarchical accretion be preserved over long timescales as in-tact dwarf satellites or as tidal debris and can be easily distinguished from the underlying smooth structure. Stellar haloes, however, remain some of the most difficult galactic structures to constrain due to their large angular extent and extremely low surface brightness. Thus, the basic properties of

stellar haloes -- the overall stellar distribution, substructure fraction, global kinematics and detailed stellar content -- remained relatively unconstrained. In this thesis, we present several projects designed to understand the current structure and the the formation of the Andromeda (M31) stellar halo, the only stellar halo -- besides our own -- that is within reach of current ground based facilities on the large scale required to constrain the basic properties of stellar haloes. First, we describe a seven season imaging campaign comprising the backbone of the Spectroscopic and Photometric Landscape of the Andromeda Stellar Halo (SPLASH) program. This survey is unique in its application of the Washington + DDO51 filter system to select individual M31 RGB stars without spectroscopic follow up. Second, we use the SPLASH photometric survey to identify sample of halo stars at projected radii of 120 kpc, for which we have obtained spectroscopic follow-up. Third, we add this large radius sample to the existing spectroscopic results from SPLASH, and use this unique sample to explore the stellar kinematics of the halo at large radii with full azimuthal coverage. Lastly, we preview on-going work to constrain the formation of the Andromeda stellar halo, using both in-tact satellites and resolved M31 halo members as tracers of its accretion history.

330 – Gamma Ray Bursts: Phenomenology and Model

Oral Session – Maryland Ballroom D – 08 Jan 2014 02:00 pm to 03:30 pm

330.01D – UV/Optical and X-ray Flares in Gamma-ray Burst Light Curves

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We present a previously unused method for the detection of flares in Gamma-ray Burst (GRB) light curves and use this method to detect flares in the UV/optical and X-ray. The method makes use of the Bayesian Information Criterion (BIC) to analyze the residuals to fitted light curves, removing all major features of the underlying afterglow, and identifies flares through iterative fitting of the residuals to statistically determine whether any remaining features are present. These additional features are then deconstructed to identify the individual flare components: T_start, T_peak, and T_stop. Using this method we present the most complete catalogs of UV/optical and X-ray flares as observed by the NASA Swift Explorer. We also present our flare correlation analysis between the X-ray and UV/optical in an attempt to identify the source of flaring in GRBs; whether it originates from the central engine or is a feature of the afterglow itself.

330.02D – Classification, Follow-up, and Analysis of GRBs and their Early-time NIR/Optical Afterglows

Adam Morgan[1], Joshua S. Bloom[1], Daniel A. Perley[2], Pierre Christian[4], Joseph Richards[1], Stephen B. Cenko[3], Christopher R. Klein[1]
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In the study of astronomical transients, achieving knowledge from discovery is a multifaceted process which includes real-time classification to identify new events of interest, deep, multi-wavelength follow-up of individual events, and the global analysis of multi-event catalogs. Here we present a body of work encompassing each of these steps as applied to the study of gamma-ray bursts (GRBs). First, we present our work on utilizing machine-learning algorithms on early-time metrics from the Swift satellite to inform the resource allocation of follow-up telescopes in order to optimize time spent on high-redshift GRB candidates. Next, we show broadband observations and analysis of the early-time afterglow of GRB 120119A, which exhibits extreme red-to-blue color change in the first few minutes after the trigger. Model fits of this color change reveal among the best support yet for the direct detection of dust destruction in the local environment of a GRB. Finally, we present results from the PAIRITEL early-time near-infrared (NIR) afterglow catalog. The 1.3 meter PAIRITEL has autonomously observed 15 GRBs in under 4 minutes after the trigger, yielding a homogenous sample of early-time JHKs light curves. Our analysis of these events provides constraints on the NIR GRB luminosity function, direct measurements of early-time NIR color change, and constraints on burst energetics.

330.03 – Classification and Energetics of Cosmological Gamma-Ray Bursts

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We present a quantitative phenomenological classification method for cosmological Gamma-Ray Bursts (GRBs) into two known subgroups of Short & Long GRBs based on the prompt gamma-ray emission properties. The classification is intended to be universal, independently of the gamma-ray detector specifications and can be used to classify a given GRB based on its observer- or rest-frame prompt variables. We show that the joint population distribution of the four main prompt emission parameters in both classes of GRBs: the isotropic luminosity (Liso), the isotropic total emission (Eiso), the rest-frame spectral peak energy (Epz) and the rest-frame duration of the prompt emission (T90z), and the interrelations among them can be well represented by a multivariate log-normal distribution, once corrected for the detector triggering threshold. The population properties of the two classes of Long & Short GRBs bear striking similarities in the 4-dimensional space of Liso, Eiso, Epz & T90z, possibly indicating a common origin and similar mechanisms responsible for the observed correlations among the prompt emission parameters.

330.04 – Observations of GRBs at high-energy: the first Fermi LAT catalog, and a new and improved detection algorithm

Giacomo Vianello[1], Nicola Omodei[1], Vlasios Vasileiou[2], Frederic Piron[2], Soebur Razzaque[3], Giacomo Vianello[1]

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The recently-published first Fermi Large Area Telescope (LAT) Gamma-Ray Burst (GRB) catalog is a systematic study of temporal and spectral features of GRBs at high energies and covers the first 3 years of the Fermi mission. This study has led to several recent theoretical advances and challenges. We present an overview of these with particular emphasis on the newly-found temporal and spectral behaviors that are in common among GRBs with high-energy emission, comparing our results with theoretical expectations. The second LAT GRB catalog is currently in preparation. It will use a new detection algorithm that increases the detection rate by up to 40% with respect to the first catalog. We will review the improvement and preliminary results from this investigation.

330.05 – On the Metallicity Aversion of LGRBs

John Graham[1], Andrew S. Fruchter[1]
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Recently, it has been suggested that the metallicity aversion of Long-duration Gamma Ray Bursts (LGRBs) is not intrinsic to their formation, but rather a consequence of the anti-correlation between star formation and metallicity seen in the general galaxy population. To investigate this proposal, we compare the metallicity of the hosts of LGRBs, broad-lined Type Ic (Ic-bl) supernovae (SNe), and Type II SNe to each other and to the metallicity distribution of star-forming galaxies using the Sloan Digital Sky Survey (SDSS) to represent galaxies in the local universe and the Team Keck Redshift Survey (TKRS) for galaxies at intermediate redshifts. The differing metallicity distributions of LGRB hosts and the star formation in local galaxies forces us to conclude that the low-metallicity preference of LGRBs is not primarily driven by the anti-correlation between star formation and metallicity, but rather must be overwhelmingly due to the astrophysics of the LGRBs themselves. Three quarters of our LGRB sample are found at metallicities below 12+log(O/H) < 8.6, while less than a one-tenth of local star formation is at similarly low metallicities. However, our SN samples are statistically consistent with the metallicity distribution of the general galaxy population. Additionally, we show that the star formation rate distribution of the LGRB and SNe host populations are consistent with the star formation rate distribution of the SDSS galaxy sample. Using the TKRS population of galaxies, we can exclude the possibility that the LGRB host metallicity aversion is caused by the decrease in galaxy metallicity with redshift, as this effect is clearly much smaller than the observed LGRB host metallicity bias over the redshift span of our sample. The presence of the strong metallicity difference between LGRBs and Type Ic-bl SNe largely eliminates the possibility that the observed LGRB metallicity bias is a byproduct of a difference in the initial mass functions of the galaxy populations. Rather, metallicity below half-solar must be a fundamental component of the evolutionary process that separates LGRBs from the vast majority of Type Ic-bl SNe and from the bulk of local star formation.

330.06 – A New Model for GRB Prompt Emission Using Multiple Spectral Components & Impact on a Epeak-Luminosity Relation for Cosmology

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Recent observations of Gamma-Ray Bursts (GRBs) with the Gamma-ray Burst Monitor (GBM) and the Large Area Telescope (LAT) onboard the Fermi Gamma Ray Space Telescope open a new window in the understanding of their prompt emission. With data sets from instruments prior to Fermi, GRB prompt emission spectra were adequately fit with the empirical Band function. The Band function is usually associated to nonthermal emission processes. Spectral analysis over the broad energy range of GBM shows deviations from this function. These deviations are sometimes adequately fitted with an additional PL and/or an additional thermal-like component. We present here the identification of multiple spectral components in the GBM prompt emission spectra of some bright Fermi GRBs: a photospheric thermal component, a broken PL (i.e., Band function) most likely associated with synchrotron emission from electrons propagating in the GRB jet, and an additional PL. Using time integrated and detailed time-resolved spectroscopy, we show the temporal evolution of the various spectral components and their relative contributions. We will see that it is possible to associate the various spectral components with light curve structures in various energy bands. We also show that while other published analysis indicate that all the emission from some GRBs may results from the Band function component, this analysis indicates that the additional PL may overpower the other components at late time. Multi-component fits allow better constraints on the GRB prompt emission spectral shape. Therefore, this new approach can reconcile the observations with the models which were challenging the spectral parameters of the Band function. We will discuss the interpretation of the various components in terms of emission mechanisms and acceleration processes, and we will examine the consequences on the central engine and jet properties. We show that data sets from instruments other than Fermi also support these results. Finally we describe the impact of this new model on a Epeak-Luminosity relation for cosmology.

330.07 – Jet-powered supernovae and GRBs

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Hydrodynamic simulations also allow us to explore the connection between GRBs and supernovae. Injecting a relativistic jet with a fixed amount of total energy and varying the duration over which the energy is injected produces a wide range of different events. For long injection times, the jet breaks out of the star as a collimated jet, producing a "classical" GRB. For short durations, all of jet energy is absorbed by the stellar envelope, producing an "ordinary" type Ib/c supernova. For intermediate durations, the jet fails to break out cleanly, but there is still mildly relativistic component to the supernova. This is likely similar to SN2009bb, an type Ib/c SN with bright, high-velocity radio emission but no GRB.

331 – Interstellar Medium & Dust IV

Oral Session – National Harbor 12 – 08 Jan 2014 02:00 pm to 03:30 pm

331.01 – Effects of an Embedded B-Star Wind on the Properties of a Molecular Cloud: Ophiuchus

How-Huan Chen[1], Alyssa A. Goodman[1]
1. Harvard University, Cambrdige, MA, United States.

Supernovae are often considered to be one of the main drivers of turbulence in molecular clouds. But, recent studies (Arce et al. 2010; Arce et al. 2011) find that stellar feedback from not-especially-massive B-type stars, which are much more long-lived and numerous than stars which go supernova, can account for at least half of the turbulent energy in one large nearby molecular cloud, Perseus. In the Ophiuchus cloud, we find dust emission and H-alpha mapping showing a prominent HII region surrounded by a shell of denser, warmer gas. The center of the shell coincides with rho Ophiuchii, a multiple-star system with four B-type stars forming two pairs of close binaries. In this work, we seek answers to two questions: 1) whether the energy embedded in the shell structure plausibly comes from the B-star cluste, and if so, 2) how this energy compares to the total turbulent energy in the Ophiuchus cloud.

331.02D – New Diagnostics of MHD Turbulence in the Multiphase ISM

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The current paradigm of the ISM is that it is a multiphase turbulent environment, with turbulence affecting many important processes. For the ISM this includes star formation, cosmic ray acceleration, and the evolution of structure in the diffuse ISM. This makes it important to study interstellar turbulence using the strengths of numerical studies combined with observational studies. I shall discuss progress that has been made in the development of new techniques for comparing observational data with numerical MHD simulations in the molecular medium, in neutral gas as traced by HI, and warm ionized gas as traced by synchrotron polarization.

331.03 – Ammonia Masers in W51: Interferometric Studies

Thomas L. Wilson[1]
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Contributing teams: T. E. Clarke (NRL), D. A. Boboltz NSF), C. Henkel (MPIfR), R. Mauersberger (Joint ALMA Observatory), H.A. Wootten (NRAO), N. Broulliet (Observatoire de Bordeaux), A. Baudry (Observatoire de Bordeaux), D. Despois (Observatoire de Bordeaux)

The galactic continuum sources W51D and W51e1e2 have been long recognized as remarkable centers of ammonia maser phenomena in the centimeter wavelength range. Henkel et al. (2013 A&A 549, A90) have measured 19 masers, of which 13 are newly found for W51-IRS2, otherwise known as W51D. These arise from inversion-rotation transitions. The single dish data were taken with the Effelsberg 100-m radio telescope of the MPIfR with an angular resolution of 43 arc seconds. The conclusion that these lines were caused by maser action is based on: (1) time variability, and (2) narrow linewidths. In addition, some lines showed systematic velocity variations. High brightness temperatures and compact sizes are needed to conclusively prove maser action. We have measured a sub-set of these ammonia lines with the C array of the Jansky-Very Large Array of the National Radio Astronomy Observatory in June 2013 with an angular resolution of better than 1 arc second. Source sizes, positions, excitation models and reasons why W51 shows such a plethora of masers will be presented.

331.04 – A Systematic Deuteration Survey in the Gemini OB1 Molecular Cloud

Yancy L. Shirley[1]
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Recent maps of dust continuum emission from molecular clouds at submillimeter wavelengths have made it possible to survey and to study the chemistry of entire core and clump populations within a single cloud. One very strong chemical process in star-forming regions is the fractionation of deuterium in molecules which results in an increase in the deuterium ratio many orders of magnitude over the ISM [D]/[H] ratio and provides a chemical probe of cold, dense regions. We present a survey of DCO+ 3-2 emission toward the clump population in the high-mass, star-forming Gemini OB1 molecular cloud complex identified from 1.1 mm continuum imaging by the Bolocam Galactic Plane Survey (BGPS). The peak 1.1 mm continuum positions of 52 clumps were observed with the 10m Heinrich Hertz Submillimeter Telescope operated by the Arizona Radio Observatory. We compare to observations of HCO+ and H13CO+ from the BGPS spectroscopic survey of Shirley et al. to determine the deuterium ratio. We find that DCO+ emission is detected toward 90% of the clumps with a median deuterium ratio of a few percent. DCO+ fractionation anti-correlates with gas kinetic temperature and linewidth, a measure of the amount of turbulence within the clumps.

331.05 – Young Photodissociation Complexes in NGC 6822: Stars and PDRs

Lynn Carlson[1]
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Contributing teams: Dwarf Galaxy Survey Team

I examine Photodissociation Region (PDR) properties in relation to stellar populations in three regions of NGC 6822. This Local Group dwarf galaxy has a metallicity less than half Solar and lies 490kpc away. It is close enough that stellar populations are resolved as are nebular structures of evolving young HII regions; we can see that these regions are being driven by O/B stars. We model the radiation field directly from the stellar content and find that it matches the radiation structure determined from far-infrared (FIR) line ratios from Herschel/PACS spectral maps (in [CII], [OI] 63micron, and [OIII] 88micron) and derived total FIR maps from dust spectral energy distribution fitting. This allows us to constrain the radiation and density structure of the PDR. Finally, with mid-IR [SIII] line ratios, we map the ionized gas density. At this distance, Spitzer images are insufficient to confirm continuing star formation in these regions via the identification of Young Stellar Objects (YSOs), but the evolutionary picture and ISM density distribution indicate that we are likely to find YSOs with the advent of JWST.

331.06 – The chemical inventory of pre/proto-stellar cores

Nuria Marcelino[1], Jose Cernicharo[2], Evelyne Roueff[3], Maryvonne Gerin[4], Asuncion Fuente[5]
1. National Radio Astronomy Observatory, Charlottesville, VA, United States. 2. Centro de Astrobiologia. INTA-CSIC, Madrid, Spain. 3. Observatoire de Paris-Meudon, Meudon, France. 4. Laboratoire de Radioastronomie ENS-LERMA, Paris, France. 5. Observatorio Astronomico Nacional, Madrid, Spain.

Cold dark clouds are the sites of low-mass star formation and future planetary systems. The lack of internal heating sources and violent physical processes, like shocks, make these dense and quiescent cores the best sites to explore and to model interstellar gas-phase chemistry and molecular depletion into the dust grain surfaces. However, they have been found to be less chemically simple than previously thought. A previous limited scan between 86-93 GHz toward four dense cores demonstrated spectral line surveys are the best tool to provide a complete view of their molecular complexity. Indeed, three new molecular species were detected for the first time in space (D2CS, CH2CHCHO3, and HCNO), which have become an important piece of information for chemical models. Furthermore, unexpected species can provide new information about the physical and chemical evolution of molecular cores toward star formation and complement the usual tracers. Motivated by the results of this pioneering study and the recent upgrades at the IRAM 30m, providing higher sensitivity and larger instantaneous bandwidth, we performed a survey of the whole 3mm band (82.5-117.5 GHz) toward two of the cores previously observed: B1-b in Perseus and TMC-1 in Taurus. Cernicharo et al. (2012) presented the first results from this survey including new and unexpected detections in B1-b: the discovery of the methoxy radical (CH3O) and the observation of other complex molecular species (COMs). The presence of such complex species is surprising and challenge current chemical models, since they are usually observed in hot core and corinos, where the high temperatures (>100 K) allow the evaporation of ice-mantle species. Here we present the results of the full 35 GHz scan in B1-b. So far, we have detected 325 lines from 109 molecular species and isotopomers. A total of 190 lines remain unidentified. We will show the obtained abundances and compare the results of particular species in both sources, like COMs which are not detected in TMC-1. The different chemical composition observed could be characteristic of the cloud (carbon or oxygen rich environment, presence of UV photons, etc.), but it could also be the result of very early star formation activity.

331.07 – Hydrogen Halides in the Local Universe

Raquel R. Monje[1], Dariusz C. Lis[1], Thomas G. Phillips[1], David A. Neufeld[2]
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The Herschel Space Observatory has provided a unique opportunity to study hydride molecules with large rotational constant in the interstellar medium (ISM) within the nearby universe. Some of the key results from hydride studies with Herschel, and in particular with the Heterodyne Instrument for the Far-Infrared (HIFI), are the first detection at high spectral resolution of the fundamental $J = 1 - 0$ rotational transition of hydrogen fluoride (HF) at 1.232 THz, and the discovery of its ubiquitous nature within the ISM of the Milky Way galaxy and nearby galaxies. The remarkable Herschel/ HIFI results suggest, that the HF $J = 1 – 0$ transition promises to yield an extremely sensitive probe of the diffuse molecular gas along the lines of sight toward background far-infrared continuum sources and, as predicted earlier by chemical models, a valuable surrogate for molecular hydrogen in the nearby and high redshift universe. HIFI has also allowed easy observations of the two hydrogen chloride isotopologues, H35Cl and H37Cl, towards massive star-forming regions and the detection for the first time of HCl in diffuse clouds and two Cl-bearing molecules (HCl+ and H2Cl+) which play a main role in the chlorine chemistry of diffuse clouds. These and other interesting results on hydrogen halides from Herschel observations will be presented, as well as the results from follow-up studies from ground-base facilities on hydride molecules towards luminous lensed high-redshifted galaxies with strong submillimeter continuum.

332 – Large Scale Structure & Cosmic Distance II
Oral Session – National Harbor 4 – 08 Jan 2014 02:00 pm to 03:30 pm

332.01D – The Nature of the Cross-Correlation Between the Unresolved near-IR and X-ray Backgrounds: Contributions of Galaxies, AGN and Diffuse Emissions

Kari Helgason[1,2], Nico Cappelluti[3], Guenther Hasinger[4], Alexander Kashlinsky[2], Massimo Ricotti[1]
1. University of Maryland College Park, College Park, MD, United States. 2. NASA GSFC, Greenbelt, MD, United States. 3. INAF-Osservatorio Astronomico di Bologna, Bologna, Italy. 4. IfA University of Hawaii, Honolulu, HI, United States.

A spatial clustering signal has been established by Spitzer/IRAC measurements of the unresolved Cosmic near-Infrared Background (CIB) out to large angular scales, ~1 deg. We study contributions from extragalactic populations to the positive cross correlation signal of the CIB fluctuations with the Cosmic soft X-ray Background (CXB) measured with Chandra in a region overlapping with Spitzer SEDS coverage. We model the X-ray emission from AGN, normal galaxies and hot gas residing in collapsed structures, calculating their CXB fluctuations including spatial correlations with all infrared emitting counterparts. We find that these populations are unable to account for all of the measured cross power between 4.5mic and 0.5-2 keV. The discrepancy can be traced to the lack of power on scales >1 arcmin suggesting that the large scale signal originates from the same population producing the clustering seen in the unresolved CIB fluctuations. On small scales however, we find that the cross power can be explained by normal galaxies and AGN. Our analysis therefore allows for a cross CIB-CXB component produced by accreting sources at high redshifts. Provided that the high-z sources cluster with ?F/F>3%, the energy requirements are within the unresolved CXB and CIB limits placed by ?-ray attenuation studies.

332.02 – The Large-Scale-Structural evolution of galaxies in the CANDELS and COSMOS fields

Behnam Darvish[1], Bahram Mobasher[1]
1. University of California, Riverside, Riverside, CA, United States.
Contributing teams: CANDELS team, COSMOS team

We study the environmental effects on the evolution of galaxies in a variety of density regions as well as different cosmic structures(filaments, clusters and field) for a Ks<24 selected sample of ~190,000 galaxies at 0.1<z<3 in the COSMOS field and for a smaller but deeper sample of WFC3 H<26 selected galaxies in the CANDELS fields. Surface density measures are estimated using the weighted versions of the k-nearest-neighbor,adaptive kernel estimator, Voronoi tessellation and Delaunay tessellation methods; Each estimation method is tested with intensive Monte-Carlo simulations. We find that there is an overall good agreement between the surface densities estimated with different estimation methods. Using the measured density assigned to each individual galaxy, we observe a strong environmental (surface density) dependence in the color, spectral type, morphology, sSFR and stellar mass of galaxies, especially at z~< 0.5. We later use the Multi-scale Morphology Filter (MMF) algorithm which utilizes the eigenvalues of the Hessian matrix of the surface density in order to extract signals for different cosmic structures, such as filaments and clusters, and correlate these signals to our sample galaxies. A preliminary study of the extracted signals shows a strong correlation between cosmic structures and the above-mentioned properties of galaxies.

332.03 – Bridging the gap between theory and observations of galaxies across cosmic times

Yuexing Li[1], Qirong Zhu[1], Xinghai Zhao[1], Hidenobu Yajima[2]
1. Penn State University, University Park, PA, United States. 2. The University of Edinburgh, Edinburgh, Midlothian, United Kingdom.

A major recent milestone in observational cosmology is the detection of a large number of galaxies and quasars across cosmic times through multi-wavelength surveys. In order to interpret the wealth of data and to understand the origin and destination of these objects, a comprehensive model which fully accounts for the formation, evolution and multi-band properties of structures is imperative. However, despite the strong observational push, theoretical modeling in this field has lagged behind. Here, I report some progresses my group made recently in bridging this gap. We have developed a physical model for cosmological simulations which for the first time self-consistently reproduces both observed cosmic histories of star formation and black hole accretion, and a state-of-the-art radiative transfer code which offers direct comparisons between simulations and observations of galaxies over a wide range of wavelengths. By combining multi-scale cosmological simulations and multi-wavelength radiative transfer, I will present new results of the formation and evolution of galaxies and quasars at different redshifts, and the underlying physical processes that determine their properties. Furthermore, I'll discuss the detectability of the first galaxies with the next generation instruments such as JWST and ALMA.

332.04D – Assembly Bias Has a Non-monotonic Dependence on Halo Age

Jean P. Walker[1], Eric J. Gawiser[1], Nelson Padilla[2]
1. Rutgers University, Piscataway, NJ, United States. 2. Pontificia Universidad Católica de Chile, Santiago, Chile.

Cosmological theory has long been known to predict an increase in clustering strength with dark matter halo mass. Research by Gao et al. (2005, MNRAS 363, L66) found that clustering strength also increases with halo age in low mass halos. This behavior, along with other parameters that affect clustering, is referred to as "assembly bias". The goal of this dissertation is to understand the relationship between halo age and bias in order to improve the design and interpretation of large-scale cosmological surveys. Applying an improved definition of halo age to the Millennium-II simulation halo catalogs (Boylan-Kolchin 2009, MNRAS 398, 1150), we find the surprising result that, at z=0, the 20% youngest and 20% oldest halos both have elevated clustering amplitude compared to other halos of a given mass (Walker-Soler et al. 2013, in prep). Lyman Alpha Emitting galaxies (LAEs) are believed to represent the youngest galaxies at a given epoch. This makes large-scale cosmological surveys of LAEs, such as HETDEX, sensitive to assembly bias. We undertook the first study of the possible assembly bias of high-redshift LAEs and studied the evolution of mock LAE catalogs. We found the descendants of z=3.1 LAEs to be ~L* galaxies at z=0 irrespective of assembly bias but note that large uncertainties in their observed clustering make it difficult to predict the amplitude of their assembly bias (Walker-Soler et al. 2012, ApJ 752, 160).

333 – Public Policy: Perspectives from Congressional and White House Staff

Special Session – Potomac Ballroom A – 08 Jan 2014 02:00 pm to 03:30 pm

Funding for astronomy projects and research support in the US is in jeopardy due to deficit reduction measures. There may be improving prospects as the Nation's economy improves, but all depends on the support that science receives in the administration and Congress. This is a good time for a lively panel discussion at the AAS involving science staff members from Congress and the White House. Having the meeting in Washington provides a unique opportunity to attract an expert panel. Panel members will be given questions to answer to stimulate discussion. There will also be time for audience questions.

334 – Stars - Brown Dwarfs and YSOs

Oral Session – National Harbor 13 – 08 Jan 2014 02:00 pm to 03:30 pm

334.01 – Retrieval of Temperatures and Abundances in Brown Dwarf Atmospheres

Michael R. Line[1], Jonathan J. Fortney[1], Mark S. Marley[2], Caroline Morley[1]
1. University of California-Santa Cruz, Santa Cruz, CA, United States. 2. NASA Ames Research Center, Mountain View , CA, United States.

Hi-resolution infrared spectra of brown dwarfs have the potential to tell us about their temperature structures and molecular abundances. With such information we can explore the atmospheric chemistry and dynamics within the brown dwarf atmospheres. The standard approach to interpreting brown dwarf spectra has been through the use of self-consistent stellar grid models that attempt to fit basic stellar parameters such as the effective temperature and surface gravity and occasionally eddy diffusivity. We present a novel inverse approach based upon earth and solar system atmosphere remote sensing techniques to determine the detailed temperature profile, molecular gas abundances, surface gravity, photometric radius (if distance is known), and cloud properties in brown dwarf atmospheres without the need for grid models. Such an approach makes few assumptions about the nature of the molecular compositions and temperature structure, thus obtaining an unbiased estimate of the atmospheric properties. The method is sensitive to deviations from radiative-convective equilibrium, non-solar abundances, and non-standard abundance ratios. We first validate this approach on a synthetic brown dwarf spectrum. Second we apply this retrieval approach to the well-studied brown dwarf Gl 570D.

334.02 – Cloud Indicators in the Spectrum of the Closest Brown Dwarf Binary System

Jacqueline K. Faherty[1, 2]
1. Carnegie Institution of Washington, Washington, DC, United States. 2. American Museum of Natural History, New York, NY, United States.

The recent discovery of a brown dwarf binary system only 2.0+/-0.15pc away offers a new laboratory for studying the physics of low-temperature atmospheres (Luhman et al. 2013). The Luhman 16AB system is an L7.5+T0.5 1.5'' (3 AU) binary with trademark signatures of a turbulent atmosphere. Photometric monitoring of the systems combined light shows strong photometric variability across its quasi-periodic (P=4.87 +/-0.01h) light curve (Gillon et al. 2013). The peak to peak amplitude change of up to 11% is attributed to weather patterns with rapidly changing cloud structures. The components are near equal temperatures yet there is strong evidence that only the slightly cooler secondary is varying. In this talk I will show our medium resolution optical Mage and near infrared FIRE spectra of each component. We find evidence for the influence of clouds on each component but confirm that the secondary appears more affected in regions where condensate grain opacity (clouds) dominates.

334.03 – LHS 6343: Precise Constraints on the Mass and Radius of a Transiting Brown Dwarf Discovered by Kepler

Benjamin Montet[1], John A. Johnson[2], Philip S. Muirhead[4], Avi Shporer[1, 7], Andrew Howard[3], Christoph Baranec[6], Loic Albert[5]
1. California Institute of Technology, Pasadena, CA, United States. 2. Harvard University, Cambridge, MA, United States. 3. University of Hawaii, Manoa, HI, United States. 4. Boston University, Boston, MA, United States. 5. Universite de Montreal, Montreal, QC, Canada. 6. University of Hawaii, Hilo, HI, United States. 7. Jet Propulsion Laboratory, Pasadena, CA, United States.
Contributing teams: The Robo-AO Collaboration

Despite the discovery of more than 1200 brown dwarfs, only a dozen have both a measured mass and radius. Such systems are fundamental for our understanding of brown dwarf evolution. To this end, we report an updated analysis of the mass and radius of LHS 6343C, a brown dwarf orbiting one member of an M+M binary system in the Kepler field. With visible light adaptive optics data from Robo-AO, we are able to determine the third light contribution in the Kepler bandpass from the B component directly from observations in visible wavelengths. We combine 16 quarters of transit photometry from Kepler with 33 Keck HIRES radial velocity observations to measure the brown dwarf's mass and radius with 2 percent precision. Tight constraints such as these will be critical for future brown dwarf atmospheric studies as the next generation of theoretical evolutionary models are developed.

334.04 – Unusual Slowly Rotating Brown Dwarfs Discovered through Precision Spitzer Photometry

Aren Heinze[1], Stanimir Metchev[2, 1]
1. Stony Brook University, Stony Brook, NY, United States. 2. University of Western Ontario, London, ON, Canada.

Many brown dwarfs exhibit low-amplitude rotationally modulated variability due to photospheric inhomogeneities caused by condensate clouds in their atmospheres. The Spitzer Space Telescope 'Weather on Other Worlds' (WoW) project has monitored 44 brown dwarfs at unprecedented photometric precision from space. We present one of several important new results from WoW: the discovery of brown dwarfs with unexpectedly slow rotation periods. While most brown dwarfs have periods of 2-12 hours, we have identified two with well-constrained periods of 13±1 and >20 hours, respectively, and 2 others that show more tentative evidence of longer than 20-hour periods. By serving as almost non-rotating standards, these objects will allow more accurate calibration of spectroscopic measurements of brown dwarfs' projected rotational velocities. The existence of such slowly-rotating objects also constrains models of brown dwarf formation and angular momentum evolution.

334.05D – Are Extreme T Dwarf Color Outliers Revealing Their Ages?

Gregory N. Mace[1]
1. UCLA, Los Angeles, CA, United States.

Brown dwarfs emerge as the low-mass products of the star formation process and then continue to cool. Those with temperatures between 500-1000K correspond to late-type T dwarf (? T7) spectral types. Using the Wide-field Infrared Survey Explorer (WISE) we have septupled the number of T dwarfs in this temperature regime, thereby creating a sizable sample with which to study overall trends and to identify outliers. I will present my spectrophotometric studies of this expanded population and compare the WISE discoveries to the samples revealed by 2MASS and UKIDSS. Additionally, I will discuss the newly discovered T8 subdwarf companion to Wolf 1130 and its utility as a high-gravity, low-metallicity benchmark. Late-type T dwarfs with redder J-H and bluer Y-J colors, as well as suppressed K-band flux, are likely revealing their old age. A broad survey of the most extreme late-type T dwarf color outliers can provide useful indicators of physical parameters. These indicators can then be applied to the diverse sample of directly imaged exoplanet and Y dwarf discoveries.

334.06 – The GALEX Nearby Young-Star Survey

David Rodriguez[1], Ben M. Zuckerman[2], Joel H. Kastner[3], Laura Vican[2], Michael S. Bessell[4], Jacqueline K. Faherty[5, 6], Simon Murphy[7]
1. Universidad de Chile, Santiago, Chile. 2. UCLA, Los Angeles, CA, United States. 3. Rochester Institute of Technology, Rochester, NY, United States. 4. Australian National University, Canberra, ACT, Australia. 5. Carnegie Department of Terrestrial Magnetism, Washington, DC, United States. 6. American Museum of Natural History, New York, NY, United States. 7. Astronomisches Rechen-Institut, Heidelberg, Germany.

Over the last few decades, many young stars (ages ~10-100 Myr) have been discovered in moving groups within 100 parsecs of Earth. These stars represent excellent targets for direct imaging searches of extrasolar planets during the coming decades as new imaging systems and larger telescopes are commissioned. However, if the mass functions of nearby young moving groups resembles that of the field or young, rich clusters, then the presently known membership of these nearby groups is significantly lacking in low-mass stars. We have initiated a program, the GALEX Nearby Young-Star Survey, or GALNYSS, to search for these missing M-stars. GALNYSS has combined ultraviolet data from GALEX with near-IR surveys (WISE and 2MASS), as well as kinematic information, in order to identify over 2000 candidate young low-mass stars near Earth. Spectroscopic followup is ongoing, and results thus far confirm the youthful nature of many stars among the GALNYSS sample. This suggests that our technique is capable of revealing the populations of low-mass stars that are presently missing from the nearby young moving groups. We present an overview of our survey to date, including the characteristics of the GALNYSS sample and a summary of GALNYSS's latest contributions to our knowledge of the number and membership of nearby, young stellar associations. This work is supported by NASA Astrophysics Data Analysis Program award NNX12AH37G to RIT and UCLA and Chilean FONDECYT grant 3130520 to Universidad de Chile.

334.07D – Near-Infrared *JHK* Spectroscopy of Young Stellar and Substellar Objects in Orion

Patrick Ingraham[1, 2]
1. Stanford, Stanford, CA, United States. 2. Université de Montréal, Montréal, QC, Canada.

We performed low-resolution (R~40) near-infrared (0.9-2.4 μm) multi-object spectroscopy of nearly every isolated point source having apparent H band magnitudes between 9.1 and 16.5 in the central 5'x6' of the Orion Trapezium cluster. The observations were performed over four nights at the Canada-France-Hawaii Telescope using the visiting instrument SIMON, an infrared imager and multi-object spectrograph. We present the spectra of 104 objects with accurately derived spectral types including 10 new objects having masses below the hydrogen burning limit, and 5 objects with masses below the

deuterium burning limit. The spectral classification is performed by fitting previously classified spectral templates of dwarf stars (K4-M3) and optically classified young stellar and substellar objects (M4-L0) to the entire 0.9-2.4 μm spectral energy distribution in order to assign a spectral type and visual extinction for each object. Of the 104 objects studied, 44 have been previously classified spectroscopically using various techniques. We perform a rigorous comparison between the previous classifications and our own and find them to be in good agreement. Using the dereddened H band magnitudes, the classified objects are used to create an Hertzsprung-Russell diagram for the cluster. We find that the previous age estimates of ~1 Myr to be consistent with our results. In agreement with previous studies, numerous objects are observed to have luminosities several magnitudes above the 1 Myr isochrone. Numerous objects exhibiting emission features in the J band are also reported. Using the results of our spectroscopic survey we determine the log-normal functional form of the IMF to have the coefficients of logmc and ? of -0.89±0.04 and 0.59±0.03 respectively. This result is consistent with the galactic disc IMF and the IMF of numerous other young systems.

335 – Supernovae & Nebulae IV

Oral Session – National Harbor 10 – 08 Jan 2014 02:00 pm to 03:30 pm

335.01D – Host Galaxy Spectra and Consequences for SN Typing From the SDSS SN Survey

Matt Olmstead[1], Peter Brown[1, 2], Kyle S. Dawson[1], Robert Nichol[3], Renee Hlozek[4]
1. Physics and Astronomy, University of Utah, Salt Lake City, UT, United States. 2. Texas A. & M. University, College Station, TX, United States. 3. University of Portsmouth, Portsmouth, United Kingdom. 4. Princeton University, Princeton, NJ, United States.

Host galaxy spectra from supernovae (SNe) and other transient events from the Sloan Digital Sky Survey (SDSS-II) SN Survey were obtained with SDSS and an ancillary progrom of the Baryon Oscillation Spectroscopic Survey (BOSS). With the host galaxy redshift, we determine photometric and spectroscopic properties of the host galaxy sample including velocity dispersion, specific star formation, and photometric galaxy mass. We further reclassify the SN using the photometric light curves and the spectroscopic redshift as a prior and compare to the initial SN classification. We report the efficiency and purity of the photometric SN Ia sample using different criteria on light curve quality and SALT2 parameters. Finally, we report on correlations between SN properties and host galaxy properties using principle component analysis.

335.02 – Type Ia Supernova Colors and Si II Velocities: Hierarchical Bayesian Regression with Non-Gaussian Distributions

Kaisey Mandel[1], Ryan J. Foley[2], Robert P. Kirshner[1]
1. Harvard University, Cambridge, MA, United States. 2. University of Illinois-Urbana Champaign, Urbana-Champaign, IL, United States.

Determining supernova distances with high precision and small systematic error is essential to modern constraints on the cosmic expansion history and the properties of dark energy. An interesting correlation between the expansion velocity of the SN Ia explosion and its intrinsic color has been suggested by earlier work. Since this effect is not incorporated into current schemes for SN Ia light curve analysis, there is potential for improving inferences of host galaxy dust, and thus, distance estimates. We investigate the correlations between the intrinsic colors of SN Ia and the expansion velocities measured from spectral lines. We build a hierarchical Bayesian regression model to estimate the dependence of the intrinsic colors of a SN Ia on its measured Si II line velocity. We model the deviations of apparent colors from a mean intrinsic colors-velocity relation as a combination of random intrinsic scatter, measurement error, and reddening by dust. This statistical model allows for non-Gaussian distributions of the intrinsic colors and velocities. We construct a new, fast Gibbs sampler to compute the posterior inferences of the model using observed data. The method is applied to the apparent color data from BVRI light curves and Si II velocity data for nearby SN Ia. For intrinsic BV colors, we find a significant slope of 0.021 ± 0.008 mag / (1000 km/s) under a linear model, and a mean color difference of 0.06 ± 0.02 mag between high velocity and normal velocity groups under a step function model. The impact of accounting for the peak intrinsic color-velocity correlation can result in extinction corrections as large as 0.10 mag for high velocity SN Ia and +0.05 mag for normal velocity events. We compute the deviance information criterion (DIC) to gauge whether the more complex hypotheses are justified by their improved representation of the data. The DIC favors the simple linear and step functions of intrinsic color versus velocity over no trend, while higher-order polynomials are not well-supported by the data. Velocity measurements from SN Ia spectra have a surprising potential to diminish systematic errors due to the intrinsic colors and dust that affect supernova distances.

335.03 – Inferring Ejected Masses of Type Ia Supernovae from Nearby Supernova Factory Data

Richard A. Scalzo[1], Gregory S. Aldering[2], Pierre Antilogus[3], Cecilia Aragon[2, 4], Stephen J. Bailey[2], Charles Baltay[5], Sebastien Bongard[3], Clement Buton[6], Arnaud Canto[3], Flora Cellier-Holzem[3], Michael Childress[1, 7], Nicolas Chotard[8], Yannick Copin[8], Hannah Fakhouri[2, 7], Emmanuel Gangler[8], Julien Guy[3], Marek Kowalski[6], Markus Kromer[9], Peter E. Nugent[10], Reynald Pain[3], Emmanuel Pecontal[11], Rui Pereira[8], Saul Perlmutter[2, 7], David L. Rabinowitz[5], Mickael Rigault[8], Karl Runge[2], Clare Saunders[2, 7], Stuart Sim[1, 12], Gerard Smadja[8], Charling Tao[13, 14], Stefan Taubenberger[9], Rollin Thomas[10], Benjamin Weaver[15]
1. Australian National University, Weston, ACT, Australia. 2. Lawrence Berkeley National Laboratory, Berkeley, CA, United States. 3. LPNHE, Universite Pierre et Marie Curie Paris 6, Paris, France. 4. University of Washington, Seattle, WA, United States. 5. Yale University, New Haven, CT, United States. 6. Universitat Bonn, Bonn, Germany. 7. University of California, Berkeley, Berkeley,

CA, United States. 8. Universite de Lyon, Lyon, France. 9. Max-Planck-Institut fur Astrophysik, Garching, Germany. 10. Computational Cosmology Center, LBNL, Berkeley, CA, United States. 11. CRAL, Universite Lyon 1, Lyon, France. 12. Queen's University Belfast, Belfast, United Kingdom. 13. CPPM, Marseilles, France. 14. Tsinghua University, Beijing, China. 15. New York University, New York, NY, United States.
Contributing teams: Nearby Supernova Factory

We present a sample of normal type Ia supernovae from the Nearby Supernova Factory dataset with spectrophotometry extending to sufficiently late phases to estimate the ejected mass using the bolometric light curve. We measure ^{56}Ni masses from the peak bolometric luminosity, then compare the luminosity in the ^{56}Co-decay tail to the expected rate of radioactive energy release from ejecta of a given mass. We infer the ejected mass in a Bayesian context using a semi-analytic model of the light curve, incorporating constraints from contemporary numerical models as priors on the density structure and distribution of ^{56}Ni throughout the ejecta. We discuss the interpretation of our derived mass distribution in the context of different progenitor scenarios for type Ia supernovae.

335.04 – Recurrent Novae Are Not Progenitors Of Type Ia Supernovae (Nor Are Any Binaries With Red Giant Or Sub-Giant Companion Stars)

Bradley E. Schaefer[1]
1. Louisiana State Univ., Baton Rouge, LA, United States.

I have made three tests for recurrent novae (RNe) as progenitors of Type Ia supernovae, and they decisively fail all three tests. (1) From 50% to 75% of RNe have neon-rich ejecta, so their white dwarfs are not CO composition, and they must be ejecting dredged up white dwarf material so the white dwarf is losing mass. (2) The orbital period change and ejected mass has been measured for four RNe, and all four show the white dwarf to be losing mass over each eruption cycle, with three of these measures (for U Sco in 2010, T CrB in 1946, and T Pyx in 2011) being highly significant, robust, and decisive. (3) Companion and ex-companion stars have now been sought with adequate sensitivity in many supernovae with a variety of robust methods, including looking for the ex-companion stars near the center of a Type Ia supernova remnant, early brightening in the light curve caused by a companion (the 'Kasen effect'), and looking for emission from the ejecta ramming into a prior wind. Over 100 supernova have been examined where any red giant companion should have been recognized, and over 60 supernovae have been examined where any sub-giant companion should have been recognized. Red giants or sub-giants are seen in zero of these systems. My strong conclusion is that RNe are not the progenitors of Type Ia supernovae. The third test can be extended to beyond the RNe, because we see that no supernova has any red giant or sub-giant companion star, so we can also reject all models that require such, including symbiotic stars and supersoft X-ray sources.

335.05 – Supernova Simulations with a Quark-Gluon Plasma Phase

J. Pocahontas Olson[1], Matthew Meixner[1], Grant J. Mathews[1], Lan Nguyen[2], Hollis E. Dalhed[3]
1. Physics, University of Notre Dame, Notre Dame, IN, United States. 2. Hanoi National University of Education, Hanoi, Viet Nam. 3. Lawrence Livermore National Laboratory, Livermore, CA, United States.

Recent studies have shown that a transition to a quark-gluon plasma during a core-collapse supernova could provide a mechanism to revitalize a stalled accretion shock. An Equation of State (EoS) is needed to describe the properties of matter in extremes of density and temperature, and allows us to incorporate these phases of matter in simulation. I will discuss the effects of a phase transition to quark-gluon matter in the Notre Dame Livermore Equation of State (NDL EoS), based on a Skyrme density functional theory. I demonstrate the consequences of varying the QCD bag constant and the strong coupling constant on the mass-radius relationship, and share results from runs of Notre Dame's spherically symmetric supernova simulation. The observation of a 1.97 ± 0.04 solar mass neutron star provides a stringent limit on the parameter space of a quark-gluon plasma phase in simulating supernovae collapse.

335.06 – Multidimensional Simulations of Rotating Pair Instability Supernovae

Emmanouil Chatzopoulos[1, 2]
1. Department of Astronomy & Astrophysics, University of Chicago, Chicago, IL, United States. 2. FLASH Center for Computational Science, Chicago, IL, United States.
Contributing teams: J. Craig Wheeler, Sean M. Couch

We study the effects of rotation on the dynamics, energetics and Ni-56 production of Pair Instability Supernova explosions by performing rotating two-dimensional ("2.5-D") hydrodynamics simulations. We calculate the evolution of eight low metallicity (Z = 10^-3, 10^-4 Zsun) massive (135-245 Msun) PISN progenitors with initial surface rotational velocities 50% that of the critical Keplerian value using the stellar evolution code MESA. We allow for both the inclusion and the omission of the effects of magnetic fields in the angular momentum transport and in chemical mixing, resulting in slowly-rotating and rapidly-

rotating final carbon-oxygen cores, respectively. Increased rotation for carbon-oxygen cores of the same mass and chemical stratification leads to less energetic PISN explosions that produce smaller amounts of Ni-56 due to the effect of the angular momentum barrier that develops and slows the dynamical collapse. We find a non-monotonic dependence of Ni-56 production on rotational velocity in situations when smoother composition gradients form at the outer edge of the rotating cores. In these cases, the PISN energetics are determined by the competition of two factors: the extent of chemical mixing in the outer layers of the core due to the effects of rotation in the progenitor evolution and the development of angular momentum support against collapse. Our 2.5-D PISN simulations with rotation are the first presented in the literature. They reveal hydrodynamic instabilities in several regions of the exploding star and increased explosion asymmetries with higher core rotational velocity.

336 – The Milky Way

Oral Session – Maryland Ballroom B – 08 Jan 2014 02:00 pm to 03:30 pm

336.01 – Mapping the X-Shaped Structure of the Galactic Bulge

David Nataf[1]
1. Australian National University, Canberra, ACT, Australia.
Contributing teams: Optical Gravitational Lensing Experiment

The Galactic Bar of the Milky Way has recently been shown to be bifurcated at large separations from the plane, indicative of an X-shape structure (Nataf et al. 2010; McWilliam & Zoccali 2010). In principle, this structure allows very powerful constraints as to the Galaxy's gravitational potential, but this requires accurate mapping. I discuss our efforts to characterise the morphology of the X-shape using precision investigation of the data in conjunction with stellar and dynamical simulations to forward-model the selection effects. Results are shown as to whether or not the X-shape is to be interpreted as an open-X or closed-X, and constraints as to the viewing angle between the Galactic bar's major axis and the Sun-Galactic-Center line of sight.

336.02D – The SEGUE K Giant Survey

Zhibo Ma[1], Heather L. Morrison[1], Paul Harding[1], Constance M. Rockosi[2], Young Sun Lee[3, 7], William Janesh[1, 5], Xiang-xiang Xue[4], Jennifer Johnson[6], Thomas Reding[1]
1. Case Western Reserve University, Cleveland, OH, United States. 2. UCO/Lick Observatory, Santa Cruz, CA, United States. 3. NMSU, Las Cruces, NM, United States. 4. MPIA, Heidelberg, Germany. 5. Indiana University, Bloomington, IN, United States. 6. OSU, Columbus, OH, United States. 7. MSU, East Lansing, MI, United States.
Contributing teams: SEGUE Collaboration

The SEGUE K giant survey identifies ~5000 K giants with careful spectroscopic measures of [Fe/H], log g, and estimated Bayesian distances ranging from 5 to 100 kpc. By correcting for SEGUE targeting biases we can study the distribution of [Fe/H] in situ. This sample also includes ~1800 high S/N K giants with [α/Fe] measurements and galactocentric distance out to 50 kpc. We confirm the previously measured lower [α/Fe] of the Sagittarius streams compared with the smooth halo, and extend this result to a much lower metallicity range. Moreover, we see no different [Fe/H]-[α/Fe] trends between the inner and outer smooth halo when we divide our sample at r=20 kpc.

336.03 – Relating Dark Matter to Tidal Streams with MilkyWay@home

Heidi J. Newberg[1], Matthew Newby[1], Matthew Arsenault[1], Jacob Bauer[1], Travis Desell[2], Jeffery Thompson[1], Jake Weiss[1], Malik Magdon-Ismail[1], Bolek Szymanski[1], Carlos Varela[1]
1. Rensselaer Polytechnic Inst., Troy, NY, United States. 2. University of North Dakota, Grand Forks, ND, United States.

MilkyWay@home is a 0.5 petaFLOPS volunteer computer platform that is currently measuring the spatial density of stars in the spheroid (including tidal tails of dwarf galaxies), and runs n-body simulations of dwarf galaxy tidal disruptions to compare with observations. MilkyWay@home is a very powerful engine for optimizing model parameters, using differential evolution and particle swarm techniques that were specifically adapted to our highly asynchronous and heterogeneous environment, in which each potentially best set of parameters is sent out to one of about 20,000 volunteer computers worldwide that are available at any given time. The results are returned in a few seconds or a few days or even weeks from some processors. We have already fit the spatial density of stars in the Sagittarius dwarf tidal tails using the method of statistical photometric parallax, applied to photometry for turnoff stars in the Sloan Digital Sky Survey Data Release 8 (SDSS DR8). We will soon characterize the entire volume covered by SDSS DR8. We currently compare N-body simulations (including both stars and dark matter) of dwarf galaxy tidal disruption to the measured spatial density of stars along a tidal stream, to optimize the dwarf galaxy size, mass, mass-to-light ratio, and disruption time. We are building a system that will be capable of fitting additional parameters, including: Milky Way potential (including dark matter), orbital parameters, and multiple disrupting dwarf galaxies. We will also include other observational constraints including radial velocities, distance to stream, and width of stream, all as a function of position. This research is funded by the National Science Foundation grant AST 10-09670.

336.04 – Improved Constraints on the Milky Way's Star Formation Rate and Stellar Mass from Hierarchical Bayesian Analysis

Timothy Licquia[1], Jeffrey Newman[1]
1. University of Pittsburgh, Pittsburgh, PA, United States.

We demonstrate a new method for improved estimates of several global properties of the Milky Way, including its current star formation rate (SFR), the stellar mass contained in its disk and bulge+bar components, as well as its total stellar mass. We do so by building upon the previous measurements found in the literature, combining the information contained in each of them using a hierarchical Bayesian (HB) statistical analysis that allows us to account for the possibility that any one of them may be incorrect or have underestimated its errors. In this application, the HB method yields similar estimates to a weighted average, but with more realistic error estimates. We show that this method is robust to a wide variety of assumptions about potential problems in individual measurements or error estimates. Ultimately, our analysis yields a SFR for the Galaxy of 1.66 ± 0.20 M☉ yr^{-1}. When calculating the stellar mass contained in each component of the Milky Way, we incorporate Monte Carlo simulations to reflect the latest estimates of the galactocentric radius of the sun and stellar mass surface density of the local neighborhood. We show that the mass of the Galactic bulge+bar is M*$_B = 0.91 \pm 0.08 \times 10^{10}$ M☉, the disk mass is M*$_D = 4.89^{+0.98}_{-0.82} \times 10^{10}$ M☉, and their combination yields a total stellar mass of M* $= 5.76^{+0.98}_{-0.82} \times 10^{10}$ M☉. This work displays the advantage of using HB meta-analysis to robustly combine a set of measurements that are prone to numerous systematic errors, while simultaneously providing information on the level of systematics that may be having an impact.

336.05 – A MIPSGAL 24 micron Source Catalog for the Community

Robert A. Gutermuth[1], Mark H. Heyer[1]
1. Univ. of Massachusetts, Amherst, MA, United States.

We present a full 24 micron point source catalog and 1 arcminute resolution completeness maps derived from the publicly available enhanced image products of the MIPSGAL Spitzer Legacy survey. The catalog contains slightly less than one million sources in the approximately 300 square degrees of coverage, with matched entries to the 2MASS, GLIMPSE, and WISE point source catalogs where they exist. In addition, we will show initial results from deployment of the catalog and the completeness maps to isolate intermediate mass protostars within the Bolocam Galactic Plane Survey cores in order to constrain the latency of high mass star formation. This research is supported by NASA ADAP grant NNX13AF08G.

336.06 – First hard X-ray detection of the non-thermal emission around the Arches cluster: morphology and spectral studies with NuSTAR

Roman Krivonos[1], John Tomsick[1], Franz E. Bauer[2, 3], Frederick K. Baganoff[4], Nicolas Barriere[1], Arash Bodaghee[1], Steven E. Boggs[1], Finn Christensen[5], William W. Craig[6, 1], Brian Grefenstette[7], Charles J. Hailey[8], Fiona Harrison[7], JaeSub Hong[9], Kristin Madsen[7], Kaya Mori[8], Melania Nynka[8], Daniel Stern[10], William Zhang[11]
1. Space Science Lab, UC Berkeley, Berkeley, CA, United States. 2. Instituto de Astrofisica, Facultad de Fisica, Pontificia Universidad Catlica de Chile, Santiago, Chile. 3. Space Science Institute, Boulder, CO, United States. 4. MIT Kavli Institute for Astrophysics and Space Research, Cambridge, MA, United States. 5. DTU Space - National Space Institute, Technical University of Denmark, Lyngby, Denmark. 6. Lawrence Livermore National Laboratory, Livermore, CA, United States. 7. Cahill Center for Astronomy and Astrophysics, California Institute of Technology, Pasadena, CA, United States. 8. Columbia Astrophysics Laboratory, Columbia University, New York, NY, United States. 9. Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA, United States. 10. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States. 11. NASA Goddard Space Flight Center, Greenbelt, MD, United States.
Contributing teams: The NuSTAR Team

The Arches cluster is a young, densely packed massive star cluster in our Galaxy that shows a high level of star formation activity. The nature of the extended non-thermal X-ray emission around the cluster remains unclear. The observed bright Fe K_alpha line emission at 6.4~keV from material that is neutral or in a low ionization state can be produced either by X-ray photoionization or by cosmic-ray particle bombardment or both. In this paper we report on the first detection of the extended emission around the Arches cluster above 10~keV with the \textit{NuSTAR} mission, and present results on its morphology and spectrum. The spatial distribution of the hard X-ray emission is found to be consistent with the broad region around the cluster where the 6.4~keV line is observed. The interpretation of the hard X-ray emission within the context of the X-ray reflection model puts a strong constraint on the luminosity of the possible illuminating hard X-ray source. The properties of the observed emission are also in broad agreement with the low-energy cosmic-ray proton excitation scenario.

336.07 – XMM-Newton Observations of Fermi bubbles and the Magnetic Field of the Structure

Meng Su[1]

1. MIT, Cambridge, MA, United States.

Data from the Fermi-LAT revealed two large gamma-ray bubbles, extending 50 degrees above and below the Galactic center, with a width of about 40 degrees in longitude. Such structure has been recently observed by Planck in microwave. I will show multi-wavelength studies of the Fermi bubbles including features of polarization emission and rotation measure study of the Fermi bubbles. We observe the edge of the bubbles using XMM-Newton and confirm a sharp edge in X-ray. I will also discuss the magnetic field structure of the Fermi bubbles.

336.08 – Morphology and gamma-ray spectrum of the Fermi bubbles

Dmitry Malyshev[1], Anna Franckowiak[1], Vahe Petrosian[2]
1. SLAC, KIPAC, Menlo Park, CA, United States. 2. Stanford University, Stanford, CA, United States.
Contributing teams: Fermi Large Area Telescope collaboration

The Fermi bubbles are two large structures visible in high energy gamma-rays, possibly related to past activity in or around the Galactic center. I will describe an analysis of the Fermi bubbles using 50 months of survey gamma-ray data from the Fermi Large Area Telescope (reprocessed Pass 7). Results on the spectrum and morphology of the Fermi bubbles will be presented. Implications for the formation of the bubbles and gamma-ray emission mechanisms will be discussed.

337 – The Proper Use of GRE Scores and Noncognitive Measures for Enhancing Diversity and Excellence in Astronomy Graduate Programs

Special Session – National Harbor 5 – 08 Jan 2014 02:00 pm to 03:30 pm

Standardized test scores (GREs) are a staple of graduate admissions criteria in physics and astronomy graduate programs. It has long been known that GRE scores are powerfully correlated with gender and ethnicity. New research (Miller & Stassun, 2013, Science, submitted) shows that women score on average ~60 points lower than men and African Americans score on average ~150 points lower than Caucasians on the General GRE Quantitative exam. These results apply for students who were undergraduate physical sciences majors and whose undergraduate GPAs were 3.7 or higher. It is common practice in top-tier physics and astronomy graduate programs to adopt a GRE "cutoff" on the quantitative GRE of ~700, either as a matter of policy or else as a subjective but strong weight. The new research shows that applying such a cutoff immediately eliminates more than two-thirds of women, roughly three-quarters of Hispanics, and nearly all African Americans from the applicant pool. This session will present a summary of this crucially important new research (including any similarly comprehensive research on the Physics GRE subject exam), will present complementary admissions strategies including psychometrically vetted noncognitive attributes such as "grit" that have been demonstrated to successfully predict success, and will engage the community in an open discussion of best practices for sustaining a commitment to broadened participation while maintaining standards of excellence focused on successful scientific careers. An aim of the session will be to produce a follow-up white paper for use by the community summarizing findings and recommendations.

337.01 – Using Minimum Acceptable GRE Scores for Graduate Admissions Suppresses Diversity

Casey Miller[1]

1. Univ of South Florida, Tampa, FL, United States.

I will present data showing that significant performance disparities on the GRE general test exist based on the test taker's race and gender [1]. Because of the belief that high GRE scores qualify one for graduate studies, the diversity issues faced by STEM fields may originate, at least in part, in misuse of the GRE scores by graduate admissions committees. I will quantitatively demonstrate this by showing that the combination of a hard cut-off and the different score distributions leads to the systematic underrepresentation of certain groups. I will present data from USF's PhD program that shows a lack of correlation between GRE scores and research ability; similar null results are emerging from numerous other programs. I will then discuss how assessing non-cognitive competencies in the selection process may lead to a more enlightened search for the next generation of scientists. [1] C. W. Miller, "Admissions Criteria and Diversity in Graduate School", APS News Vol 22, Issue 2, The Back Page (2013) http://www.aps.org/publications/apsnews/201302/backpage.cfm

337.02 – Why Doesn't The GRE or GPA Work in Selecting Graduate Students & What Alternatives Are There ?

William Sedlacek[1]

1. Univ of Maryland, College Park, MD, United States.

The simplest response to the title of this paper is that the measures that are commonly employed in evaluating prospective graduate and professional students don't work. That is, scores from the Graduate Record Examination (GRE) and prior grades (GPA) appear to have little validity in assessing postbaccalaureate student potential (Sternberg & Williams, 1997; Sedlacek, 1998, 2004; Bair & Haworth, 1999). Measurement problems such as restriction of range will discussed and the need to consider a multiverse statistical model presented. An alternative assessment system based on noncognitive variables will be presented and examples of its use with graduate and professional students discussed (Sedlacek, 2004, 2012, in press).

337.03 – Going beyond standardized exam scores in graduate admissions: Enhancing diversity and predicting success

Keivan Stassun[1, 2]

1. Vanderbilt University, Nashville, TN, United States. 2. Fisk University, Nashville, TN, United States.

We present the approach to graduate admissions developed by the Fisk-Vanderbilt Masters-to-PhD Bridge Program. The approach emphasizes a careful examination of applicants' basic academic preparedness together with noncognitive tracers of future success -- so-called "grit" or "performance character" -- and does not rely upon standardized exam scores such as GREs. This approach has enabled the Fisk-Vanderbilt program to identify and select large numbers of underrepresented minority students who are succeeding at the PhD level, making the program the nation's top producer of underrepresented minority PhDs in astronomy. We highlight outcomes of the program utilizing this "enlightened approach" to admissions, and share tools developed by the program for use by others.

– Panel Discussion

Lisa Idem
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338 – Astronomy and Public Policy
Plenary Session – Potomac Ballroom A – 08 Jan 2014 04:30 pm to 05:20 pm

Astronomy and Public Policy

338.01 – Astronomy and Public Policy

Nicholas B. Suntzeff[1]
1. Texas AandM University, College Station, TX, United States.

Astronomy is an unusual science in that almost all of what we study can only be passively observed. We enjoy tremendous public support for our research and education, both domestically and abroad. Our discoveries in cosmology and exoplanets have captured world-wide attention, as have stunning images from the Great Observatories of NASA, and ground based telescopes. Despite the passive nature of our science, it touches humanity profoundly. There are groups of amateur astronomers in every conceivable country who meet to look at the sky. Almost one billion people from 150 countries participated in The International Year of Astronomy 2009. No other science reaches humanity as ours does. In a recent poll, it was found that the among all the things the US does abroad, US science is seen by the world as our most positive face. We as astronomers can use this good will to affect positive changes in the world through public policy. I would like to explore how astronomy has impacted public policy, especially foreign policy, and what more we can do in the future. I also hope to encourage astronomers that a career path into public policy is an excellent use of a Ph.D. in astronomy.

339 – Preparing for Future NASA Missions: The Strategic Astrophysics Technology Program

Special Session – National Harbor 2 – 08 Jan 2014 06:30 pm to 08:00 pm

Over the next decade and beyond, NASA's Astrophysics Division anticipates soliciting space flight missions to explore the nature of the universe. These missions will study how galaxies and stars formed and evolved to shape the universe we see today, and will search out and characterize the planets and planetary systems orbiting other stars. As compelling as these future missions will be, implementing them presents many daunting technological challenges. NASA's Astrophysics Division has established the Strategic Astrophysics Technology (SAT) program to overcome these challenges and pave the way to ever more ambitious missions. The SAT program is intended to mature key technologies to the point at which they are feasible for implementation in space flight missions. In this session, NASA representatives will present an overview of the SAT program including technologies of interest for all three themes (Physics of the Cosmos, Cosmic Origins and Exoplanets), targeted technology readiness levels (TRL), and the scope of already approved investigations and their promised outcomes. Following this introduction, a series of presenters, all current participants in the SAT program, will provide a snapshot of their individual technology development and relate how they could enable or enhance future NASA missions. A companion poster session will showcase the full breadth of SAT research across all three.

339.01 – Starshades for Exoplanet Imaging and Characterization

N. J. Kasdin[1], Robert J. Vanderbei[1], Stuart Shaklan[2], Doug Lisman[2], Mark Thomson[2], Eric Cady[2], Bruce Macintosh[3], Dan Sirbu[1], Amy Lo[4]
1. Princeton University, Princeton, NJ, United States. 2. Jet Propulsion Labortory, Pasadena, CA, United States. 3. Lawrence Livermore National Laboratory, Livermore, CA, United States. 4. Northrop-Grumman Aerospace Systems, Redondo Beach, CA, United States.

An external occulter is a satellite employing a large screen, or starshade, that flies in formation with a spaceborne telescope to provide the starlight suppression needed for detecting and characterizing exoplanets. Among the advantages of using an occulter are the broadband allowed for characterization and the removal of light before entering the observatory, greatly relaxing the requirements on the telescope and instrument. In this presentation I will explain how star shades achieve high contrast through precise design and control of their shape and how we develop an error budget to establish requirements on the manufacturing and control. Raising the technology readiness level of starshades requires a sequence of activities to verify approaches to manufacturing, deployment, test, and analysis. The SAT-TDEM program has been instrumental in raising the readiness level of the most critical technology. In particular, I will show the results of our first TDEM in 2010-2012 that verified a full scale petal could be built and measured to the needed accuracy for 10 orders of magnitude of contrast. Our second TDEM in 2012-2014 verified that a starshade could be deployed and the petals could be placed to the required position to better than 1 mm. Finally, laboratory experiments have verified the optical modeling used to predict starshade performance to better than 1e-10.

339.02 – Next Generation X-ray Optics: High Angular Resolution, Light Weight, and Low Production Cost

William Zhang[1]
1. NASA's GSFC, Greenbelt, MD, United States.
Contributing teams: NGXO

X-ray telescopes are essential to the future of x-ray astronomy. In this talk I will describe a comprehensive program to advance the technology for x-ray telescopes well beyond the state of the art represented by the dour missions currently in operations: Chandra, XMM-Newton, Suzaku, and NuSTAR. This program will address the three key issues in making an x-ray telescope: (1) angular resolution, (2) effective area per unit mass, and (3) cost per unit effective area. The objectives of this technology program are (1) in the near term, to enable Explorer-class x-ray missions and an IXO-type mission, and (2) in the long term, to enable a flagship x-ray mission with sub-arcsecond angular resolution and multi-square-meter effective area, at an affordable cost. We pursue two approaches concurrently, emphasizing the first approach in the near term (2–5 years) and the second in the long term (4–10 years). The first approach is precision slumping of borosilicate glass sheets. By design and choice at the outset, this technique makes lightweight and low-cost mirrors. The development program will continue to improve angular resolution, to enable the production of 5-arcsecond x-ray telescopes, to support Explorer-class missions and one or more missions to supersede the original IXO mission. The second approach is precision polishing and light-weighting of single-crystal silicon mirrors. This approach benefits from two recent commercial developments: (1) the inexpensive and abundant availability of large blocks of monocrystalline silicon, and (2) revolutionary advances in deterministic, precision polishing of mirrors. By design and choice at the outset, this technique is capable of producing lightweight mirrors with sub-arcsecond angular resolution. The development program will increase the efficiency and reduce the cost of the polishing and the light-weighting processes, to enable the production of lightweight sub-arcsecond x-ray telescopes. Concurrent with the fabrication of lightweight mirror segments is the continued development and perfection of alignment and integration techniques, for incorporating individual mirror segments into a precision mirror assembly.

339.03 – Advanced Antenna-Coupled Superconducting Detector Arrays for CMB Polarimetry

James Bock[1,2]

1. California Institute of Technology, Pasadena, CA, United States. 2. Jet Propulsion Lab, Pasadena, CA, United States.

We are developing high-sensitivity millimeter-wave detector arrays for measuring the polarization of the cosmic microwave background (CMB). This development is directed to advance the technology readiness of the Inflation Probe mission in NASA's Physics of the Cosmos program. The Inflation Probe is a fourth-generation CMB satellite that will measure the polarization of the CMB to astrophysical limits, characterizing the inflationary polarization signal, mapping large-scale structure based on polarization induced by gravitational lensing, and mapping Galactic magnetic fields through measurements of polarized dust emission. The inflationary polarization signal is produced by a background of gravitational waves from the epoch of inflation, an exponential expansion of space-time in the early universe, with an amplitude that depends on the physical mechanism producing inflation. The inflationary polarization signal may be distinguished by its unique 'B-mode' vector properties from polarization from the density variations that predominantly source CMB temperature anisotropy. Mission concepts for the Inflation Probe are being developed in the US, Europe and Japan. The arrays are based on planar antennas that provide integral beam collimation, polarization analysis, and spectral band definition in a compact lithographed format that eliminates discrete fore-optics such as lenses and feedhorns. The antennas are coupled to transition-edge superconducting bolometers, read out with multiplexed SQUID current amplifiers. The superconducting sensors and readouts developed in this program share common technologies with NASA X-ray and FIR detector applications. Our program targets developments required for space observations, and we discuss our technical progress over the past two years and plans for future development. We are incorporating arrays into active sub-orbital and ground-based experiments, which advance technology readiness while producing state of the art CMB polarization measurements.

339.04 – Cross strip anode readouts for microchannel plate detectors: developing flight qualified prototypes.

John Vallerga[1], Michael Cooney[2], Rick Raffanti[3], Gary Varner[2], Oswald Siegmund[1], Jason B. McPhate[1], Anton Tremsin[1]

1. University of California, Berkeley, Berkeley, CA, United States. 2. University of Hawaii at Manoa, Honolulu, HI, United States. 3. Techne Instruments, Oakland, CA, United States.

Photon counting microchannel plate (MCP) imagers have been the detector of choice for most UV astronomical missions over the last two decades (eg. EUVE, FUSE, COS on Hubble etc.). Over this duration, improvements in the MCP laboratory readout technology have resulted in better spatial resolution (x10), temporal resolution (x 1000) and output event rate (x100), all the while operating at lower gain (x 10) resulting in lower high voltage requirements and longer MCP lifetimes. One such technology is the parallel cross strip (PXS) readout. The PXS anode is a set of orthogonal conducting strips (80 x 80), typically spaced at a 635 micron pitch onto which charge clouds from MCP amplified events land. Each strip has its own charge sensitive amplifier that is sampled continuously by a dedicated analog to digital (ADC) converter at 50MHz. All of the 160 ADC digital output lines are fed into a field programmable gate array (FGPA) which can detect charge events landing on the strips, measure the peak amplitudes of those charge events and calculate their spatial centroid along with their time of arrival (X,Y,T). Laboratory versions of these electronics have demonstrated < 20 microns FWHM spatial resolution, count rates on the order of 2 MHz, and temporal resolution of ~ 1ns. In 2012 the our group at U.C. Berkeley, along with our partners at the U. Hawaii, received a Strategic Astrophysics Technology grant to raise the TRL of the PXS detector from 4 to 6 by replacing most of the 19" rack mounted, high powered electronics with application specific integrated circuits (ASICs) which will lower the power, mass and volume requirements of the PXS detector. We were also tasked to design and fabricate a "standard" 50mm square active area MCP detector incorporating these electronics that can be environmentally qualified for flight (temperature, vacuum, vibration). This detector design could then be modified for individual flight opportunities with a higher level of confidence than starting from scratch. We will present the latest progress on the ASIC designs, fabrication and performance and show imaging results from the 50mm XS detector using our current laboratory PXS electronics.

339.05 – Advanced Mirror Technology Development for Very Large Space Telescopes

H. P. Stahl[1]

1. NASA, Huntsville, AL, United States.

Advanced Mirror Technology Development (AMTD) is a NASA Strategic Astrophysics Technology project to mature to TRL-6 the critical technologies needed to produce 4-m or larger flight-qualified UVOIR mirrors by 2018 so that a viable mission can be considered by the 2020 Decadal Review. The developed mirror technology must enable missions capable of both general astrophysics & ultra-high contrast observations of exoplanets. Just as JWST's architecture was driven by launch vehicle, a future UVOIR mission's architectures (monolithic, segmented or interferometric) will depend on capacities of future launch vehicles (and budget). Since we cannot predict the future, we must prepare for all potential futures. Therefore, to provide the

science community with options, we are pursuing multiple technology paths. AMTD uses a science-driven systems engineering approach. We derived engineering specifications for potential future monolithic or segmented space telescopes based on science needs and implement constraints. And we are maturing six inter-linked critical technologies to enable potential future large aperture UVOIR space telescope: 1) Large-Aperture, Low Areal Density, High Stiffness Mirrors, 2) Support Systems, 3) Mid/High Spatial Frequency Figure Error, 4) Segment Edges, 5) Segment-to-Segment Gap Phasing, and 6) Integrated Model Validation Science Advisory Team and a Systems Engineering Team. We are maturing all six technologies simultaneously because all are required to make a primary mirror assembly (PMA); and, it is the PMA's on-orbit performance which determines science return. PMA stiffness depends on substrate and support stiffness. Ability to cost-effectively eliminate mid/high spatial figure errors and polishing edges depends on substrate stiffness. On-orbit thermal and mechanical performance depends on substrate stiffness, the coefficient of thermal expansion (CTE) and thermal mass. And, segment-to-segment phasing depends on substrate & structure stiffness. This presentation will introduce the goals and objectives of the AMTD project and summarize its recent accomplishments.

340 – The Millimetron Space Mission

Special Session – National Harbor 10 – 08 Jan 2014 06:30 pm to 08:00 pm

Millimetron is a space mission approved by the Russian Space Agency, which is being developed in Russia by a government, academic, and industrial collaboration, led by Dr. N. Kardashev of the Astro Space Center in Moscow. Key parameters include a 10 m diameter deployable telescope operating to 200 microns wavelength, with central 3 m portion operating to wavelengths as short as 50 microns. The spacecraft will be in a L2 halo orbit, and the telescope cooled by a combination of radiation shields and cryocoolers to a temperature fo 4.5 K. Building on the success of the Radioastron mission (launched 18 July 2011), a major research area for Millimetron is to extend earth-space VLBI to millimeter and submillimeter wavelengths with ALMA and other facilities, covering frequencies up to 950 GHz. The highest angular resolution of 40 nanoarcseconds (2x10 in unprecedented detail of supermassive black holes, jets, and accretion processes. It will also be possible to study water megamasers with ~10 microarcseconds resolution binary objects and gravitational lenses at high redshift. Millimetron instrumentation will include a low-resolution imaging spectrometer covering 100 to 1000 GHz in 4 bands with frequency resolution of 1.25 GHz. This will be used to study the SZ effect in a large sample of clusters, and make a survey of 1000+ high z galaxies in the C+ fine structure line. A high spectral resolution multipixel heterodyne spectrometer is also envisioned, covering key spectral ranges between 350 GHz and 6000 GHz. With an angular resolution of 4" at [CII] 158 ?m and 5" at [OI] 63 ?m, dramatically detailed studies of molecular cloud formation, evolution, and star formation in nearby galaxies will be enabled, complementing CO data anticipated from ALMA. Other species that will be observable include CH, HeH+ session will review the plan for the mission, the instrumentation envisioned, and present some of the astronomical highlights of the science program.

340.01 – Millimetron Mission and Instruments

A. Smirnov[1]

1. Astro Space Center of P.N. Lebedev Physical Institute, Moscow, Russian Federation.

The Millimetron is a space-borne observatory based on a 10-m aperture deployable telescope, which will enable observations at millimeter, submillimeter and far-infrared wavelengths. Observations in these bands are indispensable for our understanding the early stages of the Universe, star and galaxy formation and many other topics. The observatory can operate in two different observation modes: as a single-dish telescope and as an element of a Space-Earth interferometer. The space telescope is cooled to a temperature less than 6K that, in combination with instruments based on a state of the art detector technology, will provide extraordinary performance for photometric and spectroscopic astronomical observations in terms of sensitivity and angular resolution. On the other hand, Millimetron is to be in a halo orbit around the L2 Lagrange point, providing an unprecedented increases the resolving power of the Space-Earth interferometer, and allowing detection of extremely small details in the astronomical targets observed. In this talk I will review the main characteristics of the Millimetron observatory and the capabilities of its several instruments.

340.02 – Millimetron and Earth-Space VLBI

S. Likhachev[1]

1. Astro Space Center, Moscow, Russian Federation.

The main scientific goal of the Millimetron mission operating in Space VLBI (SVLBI) mode will be the exploration of compact radio sources with extremely high angular resolution (better than one microsecond of arc). The space-ground interferometer Millimetron has an orbit around L2 point of the Earth – Sun system and allows operating with baselines up to a hundred Earth diameters. SVLBI observations will be accomplished by space and ground-based radio telescopes simultaneously. At the space telescope the received baseband signal is digitized and then transferred to the onboard memory storage (up to 100TB). The scientific and service data transfer to the ground tracking station is performed by means of both synchronization and communication radio links (1 GBps). Then the array of the scientific data is processed at the correlation center. Due to the (u,v) - plane coverage requirements for SVLBI imaging, it is necessary to propose observations at two different frequencies and two circular polarizations simultaneously with frequency switching. The total recording bandwidth (2x2x4 GHz) defines of the on-board memory size. The ground based support of the Millimetron mission in the VLBI-mode could be Atacama Large Millimeter Array (ALMA), Pico Valletta (Spain), Plateau de Bure interferometer (France), SMT telescope in the US (Arizona), LMT antenna (Mexico), SMA array, (Mauna Kea, USA), as well as the Green Bank and Effelsberg 100 m telescopes (for 22 GHz observations). We will present simulation results for Millimetron-ALMA interferometer. The sensitivity estimate of the space-ground interferometer will be compared to the requirements of the scientific goals of the mission. The possibility of multi-frequency synthesis (MFS) to obtain high quality images will also be considered.

340.03 – Millimetron and Submillimeter Spectroscopy

Paul Goldsmith[1]

1. JPL, Pasadena, CA, United States.

The Millimetron space mission includes a 10m diameter deployable telescope operating to wavelengths as short as 200 microns, with the central 3 m portion operating to wavelengths as short as 50 microns. The 6K aperture offers an enormous increase in sensitivity for photometry and low resolution for spectroscopy, which will yield important new information about

the galaxies studied by Herschel, as well as more distant sources. For high spectral-resolution Galactic spectroscopy the primary advantage relative to Herschel HIFI is the 3 times larger diameter. The rich results from Herschel HIFI suggest numerous investigations for Millimetron using molecular, atomic, and ionic lines probing the structure of the Milky Way and nearby galaxies, and investigating various stages of star formation. The 4" angular resolution at the 158 μm fine structure line of ionized carbon together with a focal plane array spectrometer will enable mapping of the spiral structure in nearby galaxies to determine the evolution of clouds and their relationship to newly-formed stars. [CII] is a critical tracer for understanding the formation of the filamentary structure found to be ubiquitous in the interstellar medium. This line will let us probe the complete evolutionary pattern of material from diffuse to dense form, yielding critical information on what determines the rate of star formation. High-J CO lines will be used to provide information about shocks and other heating mechanisms in the interstellar medium, as well as molecular outflows and the environments of young stars. While it has proven difficult to detect water in protostellar disks, the improved sensitivity of Millimetron will dramatically improve our ability to study this important molecule. Water and other molecules including HDO can be observed in solar system objects as well, allowing study of the connection between the solar system and molecular clouds. In this talk I will present a selective overview of Millimetron's capabilities for spectroscopy of the Milky Way and nearby galaxies, and indicate some representative projects of particular interest that highlight the enormous capabilities of this new space observatory.

340.04 – Millimetron and the universe of galaxies and clusters

Paolo de Bernardis[1]
1. University La Sapienza, Roma, Italy, Italy.
Contributing teams: the MRI collaboration

The Sunyaev-Zeldovich effect (SZE) provides a unique tool to study low density ionized regions as can be found in clusters of galaxies, in the lobes of radio galaxies and in several other environments. In this talk we discuss the scientific potential of a differential Fourier Transform Spectrometer in the focal plane of the Millimetron mission, with focus on the detection, accurate characterization, and scientific exploitation of the SZE for cosmological and astrophysical applications. The instrument is photon-noise limited, with a background dominated by astrophysical sources and telescope emission. The covered spectral range is divided in four bands (100-200, 130-350, 350-700, 700-1000 GHz) with spectral resolution around 1 GHz, angular resolution ranging from 1.3' and 0.18', and sensitivity of a few tens fW/GHz (1s of integration, standard deviation) for each detector. The four focal planes are Nyquist-sampled by a few hundred detectors. We find that the unique combination of precision, spectral coverage and angular resolution of such an instrument allows us to use the SZE as an unbiased cosmology probe and as a powerful diagnostic of intracluster plasmas and radiogalaxy lobes.

340.05 – Millimetron Cosmology and Fundamental Physics

Sergio Colafrancesco[1,2]
1. WITS University, Johannesburg, South Africa. 2. SKA South Africa, Johannesburg, South Africa.

The unprecedented sensitivity, spatial resolution and spectro-polarimetric capabilities of the Millimetron space mission will offer unique opportunities to address crucial questions in the areas of Cosmology and Fundamental Astrophysics. I will present in this talk a selective overview of Millimetron's capabilities in addressing questions of fundamental interest in Cosmology and Astrophysics, among which: the physical nature of Dark Matter (DM), the Homogeneity (H) of the Universe and the Copernican Principle (CP), the origin of cosmological magnetic fields (B), the law of Gravity (G) at work in extreme regimes, and the fundamental properties of photons (?).

340.06 – Millimetron in the age of ALMA

Thijs de Graauw[1]
1. Astro Space Centre of P.N. Lebedev Physical Institute, Moscow, Russian Federation.

Millimetron will be launched at a time when Atacama Large (sub)Mm Array (ALMA) has gone into full operation and with fully extended capabilities covering the complete submillimeter spectra range, Planck and Herschel results have been analyzed, JWST is in orbit and the probably the first "extremely large telescopes" are coming on-line. In addition, several other ground-based sub-mm and mm experiments will also have delivered new and exciting results like the S-Z Array and the SPT. The Early Science observations with ALMA have already shown the transformational capabilities of ALMA in a variety of science areas ranging from planet forming gas streams, circum-stellar disks to early-universe star-bursts and an unexpected high degree of lensing. This is not only due to the increased sensitivity provided by the larger collecting area, but is also from the high spectral resolution with radio techniques. From these ALMA observations, it is evident that the instrumentation suite of Millimetron needs to be closely matched to ALMA's capabilities but also has to take into account the results of the successful space missions and other ground-based submm telescopes. On the other hand, Millimetron's deep spectral and photometric not-source-confused surveys in the FIR are expected to feed ALMA, JWST and ELTs with new targets. In this talk I will present and discuss highlights of ALMA and Herschel that are of relevance for the definition and optimization of the Millimetron mission and its instrumentation.

341 – Wide Field InfraRed Space Telescope (WFIRST)

Special Session – National Harbor 3 – 08 Jan 2014 06:30 pm to 08:00 pm

WFIRST is the top ranked large space mission of the Astro2010 Decadal Survey. NASA has recently acquired two "Hubble class" 2.4m mirror telescopes, one of which is being baselined for WFIRST. The NASA name for this configuration of the mission is the Astrophysics Focused Telescope Assets (AFTA). The predicted performance is impressive with IR surveys covering 1000's of square degrees to 27th magnitude. In addition to a wide-field imaging camera with a grism and an IFU spectrograph, a high contrast coronagraph will significantly advance exoplanet direct imaging, the highest ranked ASTRO2010 mid-scale priority. Observing time will be available to the community through a vigorous Guest Investigator program. The mission will make large advances in studies of dark energy, exoplanets, galaxy formation and many other areas of extragalactic, galactic and solar system astrophysics. This session will examine the scientific opportunities made available by the utilization of one of the 2.4m telescopes for the WFIRST-AFTA mission.

341.01 – How a 2.4 meter telescope makes WFIRST a more powerful and wide-randing mission

David N. Spergel[1]
1. Princeton Univ. Obs., Princeton, NJ, United States.

A 2.4-meter space telescope equipped with a very wide-field infrared camera would revolutionize astrophysics. The transfer of this telescope asset to NASA is a boon to the US scientific community that should be utilized to produce transformative science. If used for the WFIRST mission, the 2.4-meter telescope would be significantly more capable than the smaller versions of WFIRST studied in previous SDTs. As we show here in this Report, by dividing the time on WFIRST-2.4 between dark energy, micro- lensing, and guest observer observations, gains of 50- 100% or more are expected for all. Furthermore, the 2.4-m telescope makes possible new science at the lim- it of, and beyond, what was achievable with earlier WFIRST designs. WFIRST-2.4 is not only capable of wide-field near-IR observations that are key to many of the frontier areas of astrophysics, but will do so at the resolution of HST. The 2.4-m aperture of WFIRST-2.4 collects almost 3 times as much light as the unobstructed 1.3-m SDT- DRM1 and offers a factor of 1.9 improvement in spatial resolution (point spread function effective area–- PSF), which itself provides another factor-of-two improvement in accomplishing many science programs. Compared to SDT-DRM1, the design presented in our report has a ~30% smaller field-of-view (FOV) that moderates these gains, but the higher spatial resolution takes the WFIRST-2.4 program to the "next level" and sets it apart from DRM1 and — for the dark energy program specifically — the Euclid mission. In particular, having the greater speed of the larger aperture and the sharper PSF allows WFIRST-2.4 to reach a factor-of-two deep- er per unit time over an unprecedentedly large field for a large space telescope, ~90 times bigger than the HST–ACS FOV, and ~200 times bigger than the IR channel of WFC3 that has been a tremendously successful scientific tool. A coronagraph on WFIRST-2.4 would be an ex- citing extension in its capability that would not only characterize giant planets around the nearest stars, but also be an important step towards detecting habitable exoEarths:

341.02 – Exoplanet Demographics with WFIRST-AFTA

B. S. Gaudi[1]
1. Ohio State Univ., Columbus, OH, United States.
Contributing teams: WFIRST-AFTA Science Definition Team

Measurements of the demographics of exoplanets over a broad range of planet and host-star properties provide fundamental empirical constraints on theories of planet formation and evolution. Because of its unique sensitivity to low-mass, long-period, and free-floating planets, microlensing is an essential complement to our arsenal of planet detection methods. I outline the expected returns of a microlensing survey with WFIRST-AFTA. When combined with the results from complementary surveys such as Kepler, WFIRST-AFTA will yield a nearly complete picture of the demographics of planetary systems throughout the Galaxy, providing fundamental tests of planet formation theories, and informing our understanding of the frequency and potential habitability of low mass planets located in the habitable zones of their host stars.

341.03 – Coronagraphy on AFTA-WFIRST

N. J. Kasdin[1], Olivier Guyon[5], Thomas P. Greene[3], Bruce Macintosh[4], Wesley A. Traub[2]
1. Princeton University, Princeton, NJ, United States. 2. Jet Propulsion Laboratory, Pasadena, CA, United States. 3. NASA Ames Research Center, Mountain View, CA, United States. 4. Lawrence Livermore National Laboratory, Livermore, CA, United States. 5. University of Arizona, Tucson, AZ, United States.

When approving pre-formulation studies of WFIRST-AFTA (for Astrophysics Focused Telescope Assets), NASA included a baseline coronagraph instrument for exoplanet and debris disk imaging. The instrument is expected to obtain multiband photometry of tens of extrasolar planets in 1-5 AU orbits, and spectroscopically characterize a dozen or more. These will include known Doppler planets and potential new discoveries, with a strong goal of imaging some of the large population of 2-4 RE super-earths or sub-neptune planets implied by Kepler statistics. It will also provide unprecedented resolution and

contrast on transitional and late-stage debris disks. In this talk I'll describe the baseline coronagraph and wavefront control architecture, the technology requirements, and the expected performance, emphasizing the challenges and solutions for coronagraphy with an obscured aperture such as AFTA.

341.04 – WFIRST Supernova Dark Energy Program Capabilities

Saul Perlmutter[1]
1. UC, Berkeley, Berkeley, CA, United States.

The version of WFIRST with a 2.4-m telescope makes possible a strikingly capable supernova program. In particular, the higher throughput of this facility will allow high-signal-to-noise spectrophotometry of type Ia supernovae over a large range of redshifts, well out into the dark-matter-dominated decelerating regime. With a broad wavelength coverage it will be possible to study such supernovae without the usual K-correction sources of uncertainties and systematic errors. The ability to match supernova spectra across redshifts provides detailed characterization of the supernovae that can address evolutionary drifts among type Ia subpopulations as well as related intrinsic color drifts that can distort dust-reddening estimates. The resulting WFIRST supernova programs should make it possible to study the universe's expansion history at a level of precision competitive with that planned for the best of the other "Stage IV" techniques, providing a crucial ingredient in the cross-cutting and complementary study of dark energy.

341.05 – WFIRST dark energy observations in the context of Euclid and LSST

Rachel Bean[1]
1. Cornell Univ., Ithaca, NY, United States.

Dark energy represents one of the major challenges jointly facing physics and astronomy. In the search to understand cosmic acceleration, a variety of theoretical alternatives to Einstein's cosmological constant, including new types of matter and modifications to General Relativity, are under consideration. WFIRST, LSST and Euclid instruments will provide high resolution imaging of billions of galaxies, resolving large scale structure morphology and gravitational lensing, and precise spectroscopic positions and velocities of tens of millions of galaxies. A key outcome will be 3D maps of the distribution of matter and the strength of gravity in the cosmos to unparalleled precision, angular breadth and distances. This will enable the nature of dark energy to be understood in unparalleled detail.

341.06 – Galactic Science with WFIRST

Lynne Hillenbrand[1]
1. California Institute of Technology, Pasadena, CA, United States.

Large-scale digital sky surveys have come of age over the past decade. Existing data sets and future capabilities in infrared survey work relevant for galactic science will be summarized, along with the main science drivers.

342 – ESO: Present and Future
Plenary Session – Potomac Ballroom A – 08 Jan 2014 07:00 pm to 08:00 pm

342.01 – ESO: Present and Future

P. T. de Zeeuw[1]
1. ESO, Garching, Germany.

ESO is an intergovernmental organization for astronomy founded in 1962 by five countries. It currently has 14 Member States in Europe with Brazil poised to join as soon as the Accession Agreement has been ratified. Together these countries represent approximately 30 percent of the world's astronomers. ESO operates optical/infrared observatories on La Silla and Paranal in Chile, partners in the sub-millimeter radio observatories APEX and ALMA on Chajnantor and is about to start construction of the Extremely Large Telescope on Armazones. La Silla hosts various robotic telescopes and experiments as well as the NTT and the venerable 3.6m telescope. The former had a key role in the discovery of the accelerating expansion of the Universe and the latter hosts the ultra-stable spectrograph HARPS which is responsible for the discovery of nearly two-thirds of all confirmed exoplanets with masses below that of Neptune. On Paranal the four 8.2m units of the Very Large Telescope, the Interferometer and the survey telescopes VISTA and VST together constitute an integrated system which supports 16 powerful facility instruments, including adaptive-optics-assisted imagers and integral-field spectrographs, with half a dozen more on the way and the Extremely Large Telescope with its suite of instruments to be added in about ten years time. Scientific highlights include the characterisation of the supermassive black hole in the Galactic Centre, the first image of an exoplanet, studies of gamma-ray bursts enabled by the Rapid Response Mode and milliarcsec imaging of evolved stars and active galactic nuclei. The single dish APEX antenna, equipped with spectrometers and wide-field cameras, contributes strongly to the study of high-redshift galaxies and of star- and planet-formation. Early Science results obtained with the ALMA interferometer already demonstrate its tremendous potential for observations of the cold Universe. The plenary talk will outline the development of ESO, summarize the current program and consider perspectives for the coming decades.

400 – Engineering Considerations for Large Astrophysics Projects
Plenary Session – Potomac Ballroom A – 09 Jan 2014 08:30 am to 09:20 am

400.01 – Engineering considerations for large astrophysics projects

David W. Hogg[1,2]

1. New York Univ., New York, NY, United States. 2. Max-Planck-Institut für Astronomie, Heidelberg, Baden-Württemburg, Germany.

Modern astrophysics projects involve interactions among scientific objectives, hardware capabilities, operational constraints, and data-analysis methodologies, all mediated by complex software. I discuss trade-offs between hardware and software costs, resolve some age-old tensions between the taking of science data and calibration data, and promote some ideas about getting the most out of our data using probabilistic inference. I illustrate my points with examples taken from the SDSS, P1640, Kepler, and Euclid projects. The key idea is that we will only benefit maximally from the next generation of enormous data-taking projects if we design our operations and software with great care.

438 – The Nuclear Spectroscopic Telescope Array (NuSTAR) Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

438.01 – Public NuSTAR Archive at the HEASARC

Francis E. Marshall[1], Michael F. Corcoran[3], Stephen A. Drake[3], Edward Sabol[2], Karl Forster[4], Alan P. Smale[1], Stephanie G. Zonak[2]
1. NASA/GSFC, Greenbelt, MD, United States. 2. Adnet, Lanham, MD, United States. 3. USRA/CRESST, Greenbelt, MD, United States. 4. Caltech, Pasadena, CA, United States.

The archive for the Nuclear Spectroscopic Telescope Array mission, the first focusing high-energy X-ray mission, opened at the HEASARC on August 29, 2013. The data archive contains the output of the NuSTAR processing pipeline, including cleaned and calibrated event files and high-level scientific products. The number of public observations has grown rapidly from the initial set of 29 observations. Software for analyzing the NuSTAR data is available at the HEASARC (HEASoft release version 6.14 or later), and calibration data for NuSTAR is now in the HEASARC's Calibration Database (CALDB). Documentation of the NuSTAR mission and its analysis software is found at http://heasarc.gsfc.nasa.gov/docs/nustar/, and there is a web form to obtain expert assistance. We will report on the latest download rates of NuSTAR data.

438.02 – Sagittarius A* X-ray Flares Simultaneously Detected by NuSTAR And Chandra

Shuo Zhang[1], Nicolas Barriere[2], John Tomsick[2], Frederick K. Baganoff[3], Jason Dexter[2], Joseph Neilsen[4, 3]
1. Columbia University, New York, NY, United States. 2. UC Berkeley, Berkeley, CA, United States. 3. MIT, Cambridge, MA, United States. 4. Boston University, Boston, MA, United States.
Contributing teams: NuSTAR team

Sagittarius A* (Sgr A*) is the supermassive black hole residing at the dynamic center of our Galaxy. Although it remains in a notably underluminous state most of the time, flares were detected in X-ray and infrared bands frequently, increasing up to a few hundred fold in flux for up to a few hours. The flare emission mechanism has been under debate since the discovery, and hard X-ray observation can help to distinguish between different models. From July to October 2012, NuSTAR observed Sgr A* for three times as part of a coordinated observation campaign and detected four flares simultaneously with Chandra, including a bright flare with a flux increase factor of ~50. Here we present the joint analysis results of the four X-ray flares jointly observed and discuss its contribution to the understanding of flare emission mechanism.

438.03 – Detection of hard X-ray point sources above 10 keV in the NuSTAR Galactic Center Survey

Kaya Mori[1], Charles J. Hailey[1], John Tomsick[2], Roman Krivonos[2], JaeSub Hong[3]
1. Columbia University, New York City , NY, United States. 2. University of California Berkeley, Berkeley, CA, United States. 3. Harvard University, Boston, MA, United States.
Contributing teams: NuSTAR team

Beginning in October 2012, NuSTAR Galactic Center Survey has observed ~0.5x~1 degree field around the Galactic Center with total exposure of ~1 Msec. The covered field contains a few thousand Chandra X-ray sources (Muno 2009) but their true nature is still unknown. NuSTAR has unambiguously detected more than a dozen hard X-ray point sources above 10 keV, including two known X-ray binaries during their outbursts. We found that all the NuSTAR point sources detected above 10 keV so far have Chandra X-ray counterparts. Hard X-ray detection of these point sources suggests they are either magnetic CVs with kT ~10-30 keV thermal spectra or X-ray binaries with power-law (black hole) or cut-off power-law spectra (neutron star), and they can be spectroscopically identified by jointly analyzing NuSTAR and Chandra/XMM-Newton data. Our preliminary spectral analysis revealed several NuSTAR sources with power-law spectra extending beyond 40 keV, indicating that they are potential black hole candidates. In this poster, we will present our source detection methods, spectral analysis, variability study and IR counterpart searches.

438.04 – NGC 4151 as Revealed by <i>NuSTAR</i> and <i>Suzaku</i>

Mason Keck[1], Laura Brenneman[2], Martin Elvis[2], Felix Fuerst[3], Grzegorz M. Madejski[4], Giorgio Matt[5], Fiona Harrison[3], Daniel Stern[6, 3]
1. Boston University, Boston, MA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. California Institute of Technology, Pasadena, CA, United States. 4.

Stanford Linear Accelerator Center, Menlo Park, CA, United States. 5. Università Roma Tre, Roma, Italy. 6. NASA Jet Propulsion Laboratory, Pasadena, CA, United States.
Contributing teams: The NuSTAR team

We have performed spectral and timing analyses of simultaneous, 150 ks *NuSTAR* and *Suzaku* observations of the Seyfert 1.5 galaxy NGC 4151. We characterize and deconvolve the complex absorption, continuum, and reflection spectral features in the broadband (1-80 keV) X-ray emission from the active galactic nucleus (AGN) of NGC 4151. Our results include a near-maximal black hole spin for the supermassive black hole (SMBH) at the center of NGC 4151, a low coronal temperature, and detected variability of the absorber and coronal properties on timescales as short as six hours. These results demonstrate the power of employing *NuSTAR* in conjunction with lower-energy X-ray observatories such as *Suzaku* to measure the fundamental physical properties of AGNs and SMBHs with the greatest accuracy and precision ever achieved.

438.05 – NuSTAR observatory operations and data analysis

Karl Forster[1], Fiona Harrison[1], Brian Grefenstette[1], Kristin Madsen[1], Hiromasa Miyasaka[1], Vikram Rana[1], Min Hubbard[1], Andrew Davis[1], Matteo Perri[2, 3], Simonetta Puccetti[2, 3], Nino Spagnuolo[2], Paolo Giommi[2], Manfred Bester[4], Mark Lewis[4], Bryce Roberts[4], William W. Craig[4, 8], William Marchant[4], Craig Markwardt[6], Francis E. Marshall[6], Stephanie Zonak[7], Suzanne R. Dodd[5], Daniel Stern[5]
1. Caltech, Pasadena, CA, United States. 2. ASI-Science Data Center, Rome, Italy. 3. INAF – Osservatorio Astronomico di Roma, Monteporzio Catone, Italy. 4. Space Sciences Laboratory, UCB, Berkeley, CA, United States. 5. NASA/JPL, Pasadena, CA, United States. 6. NASA/GSFC, Greenbelt, MD, United States. 7. ADNET systems, Inc., Bethesda, MD, United States. 8. Lawrence Berkeley National Laboratory, Berkeley, CA, United States.

We present an overview of the observatory operations and science data analysis for the Nuclear Spectroscopic Telescope Array (NuSTAR) mission. Launched in June 2012, NuSTAR is the first focusing high energy (3-79 keV) X-ray observatory. The NuSTAR project is led by the California Institute of Technology (Caltech) with mission operations managed by the Space Sciences Laboratory (SSL) at the University of California, Berkeley. NuSTAR science data are processed automatically at the Science Operations Center (SOC) at Caltech, making use of the NuSTAR Data Analysis Software package (NuSTARDAS), jointly developed by the ASI Science Data Center (ASDC, Italy) and Caltech. Calibrated data from completed observations are made publicly available at NASA's High Energy Astrophysics Science Archive Center (HEASARC) at the Goddard Space Flight Center and at ASDC. The NuSTARDAS package is integrated into the multi-mission HEASoft X-ray data analysis software package, and NuSTAR calibration data are now part of the HEASARC Calibration Database. NuSTAR will complete its primary mission phase in 2014 and opportunities for the community to propose for observing time will become available through a guest investigator program as well as joint observing proposals with the XMM-Newton and Chandra observatories.

438.06 – Simultaneous Broadband Observations of Mrk 501 with NuSTAR

Amy Furniss[1], David Paneque[2], Grzegorz M. Madejski[3], Koji Noda[2], Paolo Giommi[4], Lars Fuhrmann[5], Zachary Hughes[6], Mislav Balokovic[7], Fiona Harrison[7], C. M. Urry[8]
1. Stanford University, Menlo Park, CA, United States. 2. Max-Planck-Institut für Physik, München, Germany. 3. Kavli Institute for Particle Astrophysics and Cosmology, SLAC National Accelerator Laboratory, Menlo Park, CA, United States. 4. ASI – Science Data Center, Frascati, Italy. 5. Max-Planck-Institut für Radioastronomie, Bonn, Gabon. 6. University of California, Santa Cruz, Santa Cruz, CA, United States. 7. California Institute of Technology, Pasadena, CA, United States. 8. Department of Physics, Yale University, New Haven, CT, United States.

We report on the multiwavelength campaign on Mrk 501 between May and August of 2013. NuSTAR hard X-ray observations of the very-high-enery gamma-ray blazar are supplemented with simultaneous Swift, Fermi Large Area Telescope, MAGIC and VERITAS exposures, allowing an unprecedented view of the broadband spectral energy distribution. Broadband light curves including radio and optical observations will be presented. NUSTAR observations, triggered by an elevated gamma-ray state detected with the MAGIC imaging atmospheric Cerenkov telescope, provide a detailed comparison between relatively low and high simultaneous spectral energy distributions of the source. Spectral variability observed with NuSTAR between the low and elevated states in the wide 3-70 keV band will be presented and used to extract information about the relativistic particle population and emission mechanism at work within the jet.

438.07 – A NuSTAR Perspective on the X-ray Binary Populations of Starburst Galaxies

Mihoko Yukita[1], Bret Lehmer[1, 2], Daniel R. Wik[1, 2], Ann E. Hornschemeier[2], Andrew Ptak[2, 1], Vallia Antoniou[3], Megan Argo[4], Keith Bechtol[5], Fiona Harrison[6], Roman Krivonos[7], Jean-Christophe Leyder[1], Thomas J. Maccarone[8], Daniel Stern[6], Tonia M. Venters[1], Andreas Zezas[3], William Zhang[2]
1. The Johns Hopkins University, Baltimore , MD, United States. 2. NASA Goddard Space Flight Center, Greenbelt , MD, United States. 3. Smithsonian Astrophysical Observatory, Cambridge, MA, United States. 4. ASTRON, Postbus, Dwingeloo, Netherlands. 5. Kavli Institute for Cosmological Physics, Chicago, IL, United States. 6. Caltech, Pasadena, CA, United States. 7. University of California, Berkeley, Berkeley, CA, United States. 8. Texas Tech University, Lubbock, TX, United States.
Contributing teams: NuSTAR Team

We present results from deep NuSTAR observations of the late-type star-forming galaxy M83. This is the first investigation of the spatially-resolved hard X-ray emission from a galaxy with properties comparable to the Milky Way (MW). It is part of the NuSTAR starburst/normal galaxy survey, which is comprised of six nearby galaxies spanning the star formation rate (SFR) range of 1 to 80 Msol/yr. The nuclear region and several off-nuclear point sources, including the previously known ULX sources, are detected in our NuSTAR observations. We find that M83 has an integrated galaxy-wide X-ray spectrum that rapidly declines at hard X-ray energies (>10 keV). To characterize the nature of the X-ray point sources, we construct color-color and color-luminosity diagrams in the NuSTAR bands and compare them with well studied binaries in the MW as well as the point sources in NGC 253, the pilot study of our survey. Finally, we combine our measurements of M83 with those of additional NuSTAR observed star-forming galaxies NGC 253, Arp 299, and IC 342 to construct a first empirical calibration of the hard X-ray luminosity (10-30 keV)/SFR correlation.

438.08 – NuSTAR analysis of the PWN and SNR in G21.5-0.9

Melania Nynka[1], Charles J. Hailey[1], Stephen P. Reynolds[2], Kristin Madsen[3], Brian Grefenstette[3]
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Contributing teams: NuSTAR Team

Beginning in July 2012, NuSTAR observed G21.5-0.9, a Crab-like Pulsar Wind Nebula (PWN) with centrally-peaked synchrotron emission located in the Galactic Plane. Though the object is well-studied in the radio, soft X-ray, and TeV energy bands, NuSTAR is the first focusing telescope to observe G21.5-0.9 above 10 keV. We present our analysis of the PWN itself, specifically the detection of a spectral break at 9.7 keV and the energy-dependant size of the PWN. Spatially-resolved hard X-ray images reveal the non-thermal emission along the eastern and Northern rim of the supernova (SN) shell. The implications for SN and PWN physics are discussed.

438.09 – First Results from NuSTAR observations of Galactic Center Non-thermal Filaments

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Contributing teams: NuSTAR Team

The Galactic Center is a complex and crowded region that contains many filamentary structures. While these non-thermal objects have been well-studied in various energy bands, their exact natures are still unknown. Some, such as the Chandra object G359.97-0.038, have been theorized to be pulsar wind nebula (PWN) candidates based on their soft X-ray morphology (Johnson et al. 2009). Others, most notably the Sgr A-E knot, have been attributed to either PWN candidates (Lu et al. 2003) or supernova remnant (SNR) shock fronts interacting with molecular clouds (Yusef-Zadeh et al. 2005). NuSTAR observations of the Galactic Center beginning October 2012 have unambiguously detected several X-ray bright non-thermal objects that have Chandra counterparts. Here we present NuSTAR analysis of these sources. We discuss the spectral and morphological results in the high-energy X-ray band and the subsequent implications on the natures of these structures.

438.10 – Revealing Fundamental Physical Properties of AGN with NuSTAR, XMM and Suzaku

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Contributing teams: the NuSTAR team

In its first year of operation, the NuSTAR X-ray telescope has opened a new window onto the high-energy universe by providing the first focused images and high signal-to-noise (S/N) data in the 3-80 keV band. The broad energy range of NuSTAR has revolutionized our ability to probe the physics at work in the cores of active galactic nuclei (AGN) around supermassive black holes (SMBHs). Obtaining simultaneous observations with NuSTAR and lower-energy X-ray telescopes such as XMM-Newton or Suzaku provides the best S/N across the broadband X-ray spectrum ever achieved, enabling the continuum, absorption and reflection components of these AGN to be definitively deconvolved for the first time. Isolating these components allows their physical processes to be studied with greater precision and accuracy than has hitherto been possible. We present results from three simultaneous campaigns carried out by NuSTAR in conjunction with XMM or Suzaku: IC 4329A, MCG--6-30-15 and NGC 1365. In each case, NuSTAR's unique strengths have led to unprecedented insights into coronal properties, absorbing structures and/or black hole spin.

438.11 – Results from the 2013 Multi-wavelength Campaign on Mkn 421

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Contributing teams: NuSTAR, Swift, MAGIC, VERITAS

Mkn 421 is a nearby BL Lacertae object of the high-synchrotron peaked type (HSP). Its very broad spectral energy distribution (SED) peaks in the X-ray and gamma-ray bands and can be explained as a non-thermal continuum arising from the relativistic jet seen at a small angle to the line of sight. Emission near the two peaks of the SED is dominated by cooling of high-energy electrons in the jet. To study the electron distribution and its evolution, we carried out a large coordinated multi-wavelength campaign between December 2012 and May 2013. The observations were made using space observatories (NuSTAR, Swift and Fermi), ground-based Cherenkov-array telescopes (MAGIC and VERITAS), as well as several optical and radio observatories. The range of X-ray flux observed spans nearly two orders of magnitude and includes the faintest states ever observed in Mkn 421 with sufficient spectral and temporal resolution to resolve short-timescale spectral variability. We find that at low flux the hard X-ray spectrum assumes a very soft/steep power-law shape and gradually becomes harder as the flux increases. The flux variations in the X-ray and the very high energy (VHE) gamma-ray domains are positively correlated and consistent with the expectations of the one-zone synchrotron self-Compton scenario with the up-scattering occurring in the suppressed Klein-Nishina regime. For the first time, it was observed that, for very low X-ray and VHE activity, both the low- and high-energy SED bumps shifted to substantially lower energies with respect to the typical SED of Mkn 421. The unprecedented data quality and the extension of high sensitivity above 10 keV enabled by NuSTAR have proven to be instrumental for deepening our understanding of the energy distribution of particles in relativistic jets.

438.12 – The first broadband study of a black hole transient in quiescence with NuSTAR and XMM-Newton

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Some of the most significant questions concerning the physics of accreting black holes (BHs) are addressed by studying BH transients at low mass accretion rates. This is where radio observations indicate the presence of steady and powerful jets, and quiescence is where significant accretion energy may be advected across the BH event horizon. While quiescent BHs have been studied previously at soft X-rays, the Nuclear Spectroscopic Telescope Array (NuSTAR) provides the first opportunity to extend coverage to energies above 10 keV. In 2013 October, we will observe V404 Cyg with NuSTAR (3-79 keV), XMM-Newton (0.3-12 keV), and VLA at radio frequencies. Of the known BH transients, V404 Cyg is known to have the highest quiescent flux, primarily due to its proximity (2.39+/-0.14 kpc). We will report on the broadband X-ray spectrum and a search for correlations between the hard X-ray, soft X-ray, and radio light curves.

438.13 – NuSTAR observations of SMC X-1 at two different superorbital phases

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SMC X-1 is a Roche-lobe accreting 0.71 s X-ray pulsar with a supergiant companion. The system has a 3.9 day orbital period and is eclipsing. Its X-ray lightcurve also shows a superorbital cycle, on a varying timescale of 40 to 70 d. This variability is thought to be due to a precessing, warped accretion disk which leads to varying obscuration. NuSTAR observed SMC X-1 twice in 2012, once during a minimum of its superorbital cycle and once during the decline of the following peak. The fluxes of the two observations differ by a factor of 10. We present a detailed broadband spectral analysis and comparison of the two spectra. They are well described by empirical cutoff power law models as well as by thermal Comptonization. The previously reported soft excess from the accretion disk is also tentatively detected. One spectral difference between the two superorbital phases is that the low flux spectrum shows additional absorption as well as a higher equivalent width iron line. This confirms the warped disk picture and refines sparse earlier broadband results obtained with BeppoSax and RXTE. Above 3 keV the pulse profile is only mildly energy dependent. It changes from the previously observed double peaked structure at high flux to being dominated by one peak at low flux, however. For the high flux observation we perform a detailed pulse phase resolved analysis. No strong changes in spectral shape are detected. To our knowledge this is the first such study extending to above 10 keV reported for SMC X-1 (phase dependent hard fluxes were reported for BeppoSax observations but the shape of the hard spectral component was not addressed). During the first third of the low flux observation no pulsations were detected. We discuss this, the changing hard pulse profile, and the stable phase resolved high flux spectra in terms of the warped disk picture.

438.14 – Morphology of the Galactic Center with NuSTAR

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Contributing teams: NuSTAR Team

The inner arcminutes of the Galaxy contains the highest concentration of high-energy sources in the Milky Way. Its supermassive black hole, pulsar wind nebulae (PWN), supernova remnants, X-ray binaries, and hot interstellar gas are copious emitters of X-rays and gamma-rays. NuSTAR provides a view of the X-ray (3-79 keV) band, a critical bridge between the soft X-ray and gamma-ray emission, with unprecedented angular resolution. We present the first sub-arcminute images of the Galactic Center above 20 keV, obtained with the NuSTAR telescopes. The hard X-ray emission from the Galactic Center is dominated by a diffuse component extending along the Galactic plane and a single strong source, spatially and spectrally consistent with both a cometary candidate PWN detected in soft X-rays by Chandra and the ultra-high energy gamma-ray emission detected by HESS. The dominance of these sources places strong constraints on other possible hard X-ray emitting populations near Sgr A*, including the hard X-ray source previously reported by INTEGRAL.

438.15 – NuSTAR Effective Area Calibration

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Contributing teams: NuSTAR Team

We present a summary of the effective area calibrations of the Nuclear Spectroscopic Telescope Array (NuSTAR) focal plane module detectors. Launched in June 2012, NuSTAR is the first focusing high energy (3-79 keV) X-ray observatory. NuSTAR is the first space based observatory to fly multi-layer coated optics. Multi-layer optics present unique challenges for effective area response modeling. For NuSTAR, a complete physics-based approach was used, with adjustment, to model the spectrum of the Crab Nebula as a reference source. On- and off-axis Crab observations were used to formulate a single adjustment model with a small number of parameters. Flux normalization repeatability is within 2.2% (1?) for all observations and within 0.9% for on-axis targets (<2 arcmin). Focal plane modules A and B are cross normalized within 2%. Spectral shape normalization is repeatable at better than 0.01 for a power law photon index. At low energies, neutral hydrogen absorption is repeatable at better than 0.2×10^{22} cm^{-2}. NuSTAR, Swift XRT and XMM-Newton normalizations agree to better than 15% in the 3-10 keV band.

438.16 – In Search of AGN in Starburst Galaxies with NuSTAR

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The coeval growth of supermassive black holes (SMBH) and their stellar halo hosts provides evidence that star formation and AGN activity must be closely associated, but it is not clear to what extent they must always be coordinated. A prime test of this coordination is the search for AGN activity in starburst galaxies, which by definition have high star-formation rates but whose SMBH can be illusive due to low luminosities and obscuration. NuSTAR offers a unique opportunity to detect AGN activity in starbursts because of its high-sensitivity X-ray imaging above 10 keV. We present the preliminary results of searching for X-ray emission in the starburst galaxies in the NuSTAR starburst program. To date three starbursts have been observed, Arp 299, M83, and NGC 253. Of these, only the nucleus of the western galaxy in the Arp 299 pair has been detected strongly above 20 keV, suggesting that this is the only galaxy harboring an obscured AGN. Evidence from combined Chandra and NuSTAR monitoring indicate that the SMBH in NGC 253 was nearly dormant in 2012 (L/LEdd < 10^-4); however, Chandra data from 2003 indicates that a low-luminosity AGN may have been more active a decade ago. The AGN in the western nucleus of Arp 299 is marginally Compton-thick (N_H ~ 2 x 10^24 cm^2) and also exhibits neutral Fe-K emission. We will discuss the implications of these results as well as prospects for detecting AGN in the remainder of the NuSTAR starburst sample.

438.17 – The reflection component from Cygnus X-1 in the soft state measured by NuSTAR and Suzaku

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The black hole binary Cygnus X-1 was observed in late-2012 with the Nuclear Spectroscopic Telescope Array (NuSTAR) and Suzaku, providing spectral coverage over the ~1-300 keV range. The source was in the soft state with a multi-temperature blackbody, power-law, and reflection components along with absorption from highly ionized material in the system. The high throughput of NuSTAR allows for a very high quality measurement of the complex iron line region as well as the rest of the reflection component. The iron line is clearly broadened and is well-described by a relativistic blurring model, providing an opportunity to constrain the black hole spin. Although the spin constraint depends somewhat on which continuum model is used, we obtain a>0.83 for all models that provide a good description of the spectrum. However, none of our spectral fits give a disk inclination that is consistent with the most recently reported binary values for Cyg X-1. This may indicate that there is a >13 degree misalignment between the orbital plane and the inner accretion disk (i.e., a warped accretion disk) or that there is missing physics in the spectral models.

438.18 – Observations of a hard state of 1E 1740.7-2942 by NuSTAR and INTEGRAL

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NuSTAR observed the Galactic Center microquasar 1E 1740.7-2942, also known as "the Great Annihilator", in July-August 2012, during its Performance Verification campaign. Despite the shortness of the observations (the total net exposure is 8.5 ks) the very high sensitivity of NuSTAR has allowed us to characterize in detail the spectrum of this source up to ~70 keV. A few weeks later, the flux declined significantly and the source entered a supposed quiescence state. Nearly simultaneous exposures of INTEGRAL/IBIS, taken before the drop in intensity, were used to extend the spectral coverage up to the soft gamma-ray band. This allowed for the detection of an exponential cutoff, with an e-folding energy at ~160 keV. The spectrum of the source is smooth and consistent with thermal Comptonization, with no sign of reflection or reprocessing features. A detailed analysis of the spectral and timing data is presented, including upper limits for reflection and Fe line. Finally, our results are compared with previous observations of the hard state by INTEGRAL and Suzaku.

438.19 – NuSTAR/XMM-Newton Detection of a Hard Cut-Off in Cen X-4

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The low-mass X-ray binary Cen X-4 is the closest known (1.2 kpc) quiescent neutron star transient. It had large outbursts in 1969 and 1979 but has been in quiescence ever since. Previous X-ray (0.5-10 keV) observations of the quiescent spectrum identified two spectral components: soft thermal emission from the neutron star atmosphere and a hard power-law tail of unknown origin. This is typical of the X-ray spectrum measured from quiescent neutron star transients, although the hard tail is not always clearly detected in other sources. We report here on a simultaneous observation of Cen X-4 with NuSTAR (114 ks, 3-79 keV) and XMM-Newton (26 ks, 0.3-10 keV) on 2013 January 20-23, providing the first sensitive measurement of the hard X-ray spectrum of a quiescent neutron star transient. We clearly detect a turnover of the hard spectral tail above 10 keV, which is well fit by an 18 keV thermal bremsstrahlung model. This is the first indication of the temperature and spatial distribution of the electron population giving rise to the hard component in a quiescent neutron star transient. The observed emission measure suggests that there is a large amount of material far from the neutron star, with only a very small fraction accreting onto the neutron star. With the hard spectral component well measured by the NuSTAR data, we are also able to obtain tighter constraints on the neutron star atmosphere emission from the XMM-Newton data than previously possible.

438.20 – NuSTAR discovery of a luminosity dependent cyclotron line energy in Vela X-1

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We present an analysis of NuSTAR observations of Vela X-1, making full use of the observatory's high sensitivity and high spectral resolution. We find clear evidence for two cyclotron lines, the fundamental line at 25keV and the harmonic line at 55keV. By extracting spectra with exposure times as short as 1ks, we investigate the behavior of the cyclotron lines as the flux range extends over one order of magnitude. We discover that the energy of the harmonic line is correlated with the 3-79keV X-ray flux. As Vela X-1 has a luminosity of only ~3e36 erg/s, this correlation can only be explained if the accretion column is very narrow, with a radius ~0.4km. In that case, Coulomb interactions can be strong enough to decelerate the in-falling material above the stellar surface and explain the correlation between line energy and flux. Additionally we found that the strength of the fundamental and harmonic lines are anti-correlated. We explain this by photon-spawning, where strong harmonic lines result in many spawned photons near the fundamental line energy, filling the line up to a level where it becomes undetectable. This is the first time that the evolution of the cyclotron parameters with flux can be studied in a persistent high-mass X-ray binary on short time-scales. These data are used to put constraints on the accretion geometry. We put our findings into context with comparisons to transient binaries and give an outlook to future observations.

438.21 – NuSTAR Imaging of Pulsar Wind Nebulae MSH 15-52 and the Crab

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We present NuSTAR imaging and spectral analysis of the two Pulsar Wind Nebulae (PWNe) MSH 15-52 and the Crab. PWNe are center-filled synchrotron nebulae with complex structures that provide clues to the understanding of particle acceleration and diffusion in relativistic shocks. We show NuSTAR imaging from 3 -- 78 keV of both objects and demonstrate that both nebulae reduce their size with increasing photon energy due to synchrotron burn-off. For the Crab the rate of shrinkage is consistent with theoretical estimates in the plane of the torus, but towards the N-W in the direction of the counter jet, the rate is almost a factor of 2 higher. In both PWNe, we observe the spectral index to steepen with increasing radius as a

consequence of synchrotron burn-off, but we will show that for the Crab, the spatially dependent spectrum is more complex that previously assumed, and that the line-of-sight integrated spectrum is better represented by a broken power-law with a break at ~10 keV.

439 – The Exciting Future of Cosmic Microwave Background Measurements Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

439.01 – The Primordial Inflation Explorer (PIXIE)

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The Primordial Inflation Explorer (PIXIE) is an Explorer-class mission to characterize the signature of primordial inflation through its distinctive imprint on the cosmic microwave background. An innovative optical design measures both linear polarization and the absolute intensity spectrum of the CMB and astrophysical foregrounds to background-limited sensitivity in 400 frequency channels spanning 2.5 decades in frequency from 30 GHz to 6 THz (1 cm to 50 μm wavelength). PIXIE will map the full sky in Stokes I, Q, and U parameters with angular resolution of 1.6 degrees and sensitivity 0.2 μK per 1 deg square pixel. The principal science goal is the detection and characterization of linear polarization from an inflationary epoch in the early universe, with tensor-to-scalar ratio r < 0.001 at 5 standard deviations. In addition, PIXIE will compare the CMB to a full-aperture blackbody calibrator to measure spectral distortions with sensitivity $\mu < 10^{-8}$ for the chemical potential and $y < 2 \times 10^{-9}$ for Compton distortions. Sensitivity at these levels opens a new window to the early universe, probing physical processes ranging from Big Bang cosmology to dark matter decay/annihilation to the nature of the first stars responsible for reionization. We describe the PIXIE instrument and mission architecture needed to detect the signature of an inflationary epoch in the early universe using only 4 semiconductor bolometers.

439.02 – PIPER: Primordial Inflation Polarization Explorer

Justin Lazear[1], Peter Ade[6], Dominic J. Benford[2], Charles L. Bennett[1], David T. Chuss[2], Jessie L. Dotson[2], Joseph Eimer[1], Dale J. Fixsen[2], Mark Halpern[3], James Hinderks[2], Gary F. Hinshaw[3], Kent Irwin[5], Christine Jhabvala[2], Bradley Johnson[4], Alan J. Kogut[2], Paul Mirel[2], Samuel H. Moseley[2], Johannes Staguhn[2, 1], Eric Switzer[2], Carole E. Tucker[6], Amy Weston[2], Edward Wollack[2]

1. Johns Hopkins University, Baltimore, MD, United States. 2. NASA-GSFC, Greenbelt, MD, United States. 3. University of British Columbia, Vancouver, BC, Canada. 4. Columbia University, New York, NY, United States. 5. NIST, Boulder, CO, United States. 6. Cardiff University, Cardiff, Wales, United Kingdom.

The Primordial Inflation Polarization ExploreR (PIPER) is a balloon-borne cosmic microwave background (CMB) polarization experiment searching for large-angular scale B-mode polarization to constrain Inflation in the early universe. The Inflationary Big Bang theory predicts that the epoch of inflation will result in a background of gravitational waves. These gravitational waves imprinted their unique B-mode signature on the CMB polarization, two features of which are a peak at ell ~ 80 and a "bump" below ell ~ 10 in the B-mode angular power spectrum. The ell ~ 80 "recombination" peak is the first peak caused by gravitational waves imprinting tensor (B-mode) perturbations onto the CMB spectrum during recombination. Gravitational waves at larger scales have not yet entered the horizon and may not contribute, and at smaller scales have decayed away by other interactions, giving rise to a peak at horizon scale. The ell ~ 10 "reionization" bump is caused by a similar mechanism as the recombination peak, where gravitational waves imprint B-mode perturbations into the spectrum, now at larger horizon scales. PIPER will target the reionization bump while keeping enough angular resolution to measure the recombination peak, with sensitivity down to tensor-to-scalar ratio r = 0.007. A series of flights alternating between north and south will produce nearly full-sky temperature and polarization maps and measure the low-ell spectra. 5120 transition edge sensor (TES) bolometers each with 20 arcmin beamwidth, distributed into 4 rectangular close-packed arrays maintained at 150 mK will provide small-scale resolution and sensitivity. PIPER consists of two co-aligned telescopes, each with a front-end variable-delay polarization modulator rapidly modulating either the Q or U Stokes parameters to provide polarization sensitivity and mitigate systematic errors. To achieve background-limited sensitivity, the entire instrument is enclosed in an open bucket dewar maintained at 1.5 K. PIPER will observe at frequencies 200, 270, 350, and 600 GHz to separate the CMB from polarized dust emission. I will describe the PIPER instrument and discuss the current status and expected science returns from the project.

439.03 – Feedhorn-coupled Bolometer Detectors at 40 GHz Implemented on the Cosmology Large Angular Scale Surveyor (CLASS)

David T. Chuss[1], Aamir Ali[2], John W. Appel[2], Charles L. Bennett[2], Felipe Colazo[1], Erik Crowe[1], Kevin Denis[1], Joseph Eimer[2], Thomas Essinger-Hileman[2], Tobias Marriage[2], Samuel H. Moseley[1], Karwan Rostem[1,2], Thomas Stevenson[1], Deborah Towner[1], Kongpop U-Yen[1], Edward Wollack[1], Lingzhen Zeng[3]
1. NASA's GSFC, Greenbelt, MD, United States. 2. The Johns Hopkins University, Baltimore, MD, United States. 3. Center for Astrophysics, Cambridge, MA, United States.

We have designed, produced, and tested 40 GHz feedhorn-coupled transition-edge sensor (TES) detectors using microstrip circuits on monocrystalline silicon dielectric substrates. Symmetric planar orthomode transducers (OMTs) couple two independent orthogonal linear polarization modes from feedhorns onto planar transmission lines over a broad (60 %) bandwidth. The 33-43 GHz band is defined by a combination of on-chip planar filtering and effective integrated shielding of stray light (blue leaks). The integrated stray light control is achieved over a frequency range of > 10:1. The monocrystalline silicon substrate provides a highly uniform dielectric constant that results in reliable circuit uniformity and performance. In addition, the monocrystalline silicon enables high efficiency due to its extremely low loss. The efficiency of the devices, including all integrated filtering, has been measured to be ~90 % for each polarization. The Cosmology Large Angular Scale Surveyor (CLASS) cosmic microwave background B-mode experiment is employing a 36-element focal plane of these detectors, along with similar detectors at higher frequencies, to map a large fraction of the sky.

439.04 – Observing the Large Scale CMB Polarization using Variable-delay Polarization Modulators

Nathan Miller[1], David T. Chuss[1], Edward Wollack[1], Tobias Marriage[2]
1. NASA's Goddard Space Flight Center, Greenbelt, MD, United States. 2. Johns Hopkins University, Baltimore, MD, United States.

Variable-delay polarization modulators (VPM) will be deployed on two upcoming cosmic microwave background (CMB) polarization experiments, CLASS and PIPER, whose goal is to recover the large angular scale polarization of the CMB. We investigate the effects that this VPM will have on analysis of CMB polarization data. We look at the ability of the VPM to extract the large scale cosmological signal from systematics generated by the VPM and within the telescope. The systematic effects investigated are grid misalignment, grid emission, temperature variation of the VPM, and a time varying differential gain. The systematics are modeled when simulating timestreams and propagated through map-making to measurements of both the EE and BB power spectra. We show that we can separate the systematics from the sky polarization during map-making to a level below the BB power spectrum corresponding to a tensor-to-scalar ratio of r=0.01.

439.05 – The Primordial Inflation Polarization Explorer: Science from Circular Polarization Measurements

Eric Switzer[1], Peter Ade[6], Dominic J. Benford[1], Charles L. Bennett[1], David T. Chuss[1], Jessie L. Dotson[1], Joseph Eimer[2], Dale J. Fixsen[1], Mark Halpern[3], Gary F. Hinshaw[3], Kent Irwin[5], Christine Jhabvala[1], Bradley Johnson[4], Alan J. Kogut[1], Justin Lazear[2], Paul Mirel[1], Samuel H. Moseley[1], Johannes Staguhn[1,2], Carole E. Tucker[6], Amy Weston[1], Edward Wollack[1]
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The Primordial Inflation Polarization Explorer (PIPER) is a balloon-borne CMB polarimeter designed to constrain the B-mode signature of cosmological inflation. Sequential one-day flights from Northern- and Southern- Hemisphere sites will yield maps of Stokes I, Q, U and V at 200, 270, 350 and 600 GHz over 85% of the sky. The full optical path is cooled to 1.5 K by liquid helium in the ARCADE bucket dewar, and a variable-delay polarization modulator (VPM) at the front of the optics modulates the polarization response. Independent Q and U cameras each have two 32x40 Transition Edge Sensor array receivers. In addition to its primary inflationary science goal, PIPER will also measure the circular (Stokes V) polarization to a depth similar to that of the primary linear polarization. The circular polarization has received relatively little attention in large-area surveys, with constraints from the 1980's and recent results by the Milan Polarimeter. Astrophysical circular polarization is generally tied to the presence of magnetic fields, either in relativistic plasmas or Zeeman splitting of resonances. These effects are thought to be undetectable at PIPER's frequencies and resolution, despite the depth. The expectation of a null result makes the deep Stokes V map a good cross-check for experimental systematics. More fundamentally, the fact that the sky is expected to be dark in Stokes V makes it a sector sensitive to processes such as Lorentz-violating terms in the standard model or magnetic fields in the CMB era.

439.06 – Beam characterization and systematics of Bicep2 and the Keck Array

Chin Lin Wong[1]
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Contributing teams: Bicep2/Keck Collaboration

The Bicep2 and Keck Array experiments are searching for B-mode polarization from inflationary gravitational waves in the Cosmic Microwave Background. Bicep2 and the Keck Array use small aperture, cold, on-axis refracting optics optimized to target the degree angular scales at which the inflationary B-mode polarization is expected to peak. The small aperture design allows us to fully characterize the far-field performance of the instrument on site at the South Pole using thermal and amplified sources on the ground. We describe the efforts taken to characterize the main beam shapes of each polarization sensitive bolometer, as well as the differential beam parameters of each co-located orthogonally polarized detector pair. We study the residual temperature to polarization leakage induced by the beam mismatches after the principle modes have been mitigated in the analysis.

439.07 – Measuring the CMB Dipole at 11 GHz—for cheap!

Aaron Markowitz[1], Samuel Harrison[1], Kirit Karkare[1, 2], Robert Kimbert[2], John M. Kovac[1, 2]
1. Harvard University, Cambridge, MA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

We report the design of a telescope capable of making mK-sensitivity maps of the microwave sky, with potential to map large-scale structure of the CMB and galaxy, within the budget of a classroom or amateur astronomer. This project modifies a telescope designed by Harvard's advanced undergraduate astrophysics lab course, with the goal of improving sensitivity enough to detect the CMB dipole. The telescope's design allows replication of the experiment within the resources of most similar undergraduate laboratory research courses. We use a low-noise block (LNB) receiver and a bandpass filter to amplify radiation near 10.7 GHz and remove RFI, and we rotate the telescope at constant angular velocity and elevation to provide coverage of the entire visible sky over 24 hours. Before modifications, the telescope accurately measured the isotropic CMB temperature, but interference and 1/f noise limited detection of isotropies in the microwave signal. With current modifications, the telescope can collect data continuously for over 24 hours, and produce maps used to constrain galactic and CMB signals.

440 – APOGEE - A Fresh View Into the Stellar Populations of the Milky Way Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

440.01 – APOGEE: The Apache Point Observatory Galactic Evolution Experiment

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Contributing teams: The SDSS-III/APOGEE Collaboration

The Sloan Digital Sky Survey III/Apache Point Observatory Galactic Evolution Experiment (SDSS-III/APOGEE) is the first large, high resolution, infrared (H-band: 1.51-1.68 μm) spectroscopic survey of all stellar populations of the Milky Way. APOGEE's first 3-year survey phase will target >100,000 Galactic stars, mostly red giants, with a unique, state-of-the-art spectrograph fed by 300 optical fibers from the Sloan 2.5-m telescope. APOGEE will measure the kinematical and chemical properties for a statistically significant number of stars to address numerous outstanding questions regarding Galactic structure, formation, dynamics, evolution and stellar populations. This poster summarizes aspects of the APOGEE target selection, spectrograph and fiber system, typical APOGEE spectra and their reduction, and gives a general overview of the variety of science applications to which APOGEE data are being applied. In addition, we show how the planned APOGEE-2 survey will quadruple the total sample of stars with observations from both the Northern and Southern Hemispheres.

440.02 – DR10 SDSS-III release of APOGEE data

Matthew D. Shetrone[1], Carlos Allende-Prieto[8], Timothy C. Beers[4], Katia M. Cunha[4], Damian Fabbian[8], Diane Feuillet[7], Peter M. Frinchaboy[3], Ana Elia Garcia Perez[6], Jennifer Johnson[2], Steven R. Majewski[6], David L. Nidever[5], Marc H. Pinsonneault[2], Verne V. Smith[4], Gail Zasowski[9]
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Contributing teams: The SDSS-III/APOGEE Collaboration

SDSS-III's newest release is Data Release 10 (DR10). DR10 contains the first spectra of the APO Galactic Evolution Experiment (APOGEE). APOGEE is the first high-resolution (R ~ 22,500), high signal-to-noise ratio (S/N >= 100 per resolution element), H-band (1.51 - 1.70 um) survey of all Galactic stellar populations (bulge, bar, disks, halo) with a uniform set of stellar tracers and spectral diagnostics. This poster will briefly describe the stellar sample included in DR10, review the data made available in DR10, consisting of fully calibrated, 1-d spectra radial velocities and the by-products of the APOGEE Stellar Parameters and Chemical Abundance Pipeline (ASPCAP): effective temperature, surface gravity, metallicity, and alpha, carbon and nitrogen abundances. We will also present the web tools that are available to the public and highlight the most critical warning and bad data flags.

440.03 – SDSS-III/APOGEE: Survey Target Selection

Brianne Meyer[1], Gail Zasowski[2], Peter M. Frinchaboy[1], Jennifer Johnson[3], Steven R. Majewski[4], Brett Andrews[3], S. Drew Chojnowski[4], Damian Fabbian[8], Michael R. Hayden[7], Fred Hearty[4], Kelly Jackson[5], David L. Nidever[6], Michael F. Skrutskie[4]
1. TCU, Fort Worth, TX, United States. 2. JHU, Baltimore, MD, United States. 3. OSU, Columbus, OH, United States. 4. UVA, Charlottesville, VA, United States. 5. UT Dallas, Dallas, TX, United States. 6. U Michigan, Ann Arbor, MI, United States. 7. NMSU, Las Crusas, NM, United States. 8. IAC, La Laguna , Spain.

The Sloan Digital Sky Survey III/Apache Point Observatory Galactic Evolution Experiment (SDSS-III/APOGEE) is a high resolution H-band (1.51-1.68 μ) spectroscopic survey covering all Galactic populations within the Milky Way. During the survey's three-year lifetime, we plan to target 100,000 Galactic stars, mostly red giants, from within the disk, bulge, and halo. Target selection is primarily based on near-infrared 2MASS data, and we use the RJCE method with mid-infrared photometry from GLIMPSE and WISE to correct for the effects of reddening and extinction. We also employ Washington+DDO51 photometry in selected fields to further reduce dwarf contamination in the targeted sample. We present the algorithms used in the selection of the general survey sample and cluster samples. Open clusters falling serendipitously in the targeted fields require a separate technique to most efficiently select cluster candidate members, and we present the selection procedure used for these targets which are part of the OCCAM survey.

440.04 – The APOGEE Data Reduction pipeline

Jon A. Holtzman[1], David L. Nidever[2], Duy Cuong Nguyen[3], Matthew D. Shetrone[4], Steven Majewski[5], Ricardo P. Schiavon[6]

1. New Mexico State Univ., Las Cruces, NM, United States. 2. University of Michigan, Ann Arbor, MI, United States. 3. University of Toronto, Toronto, ON, Canada. 4. McDonald Observatory, Fort Davis, TX, United States. 5. University of Virginia, Charlottesville, VA, United States. 6. Liverpool John Moores, Liverpool, United Kingdom.

The SDSS-III APOGEE survey is obtaining hundreds of thousands of individual high resolution near-IR spectra of Milky Way stars. Data are accumulated in data cubes, with individual non-destructive readouts occuring every 10 seconds, across three separate HgCdTe detectors. Exposures are obtained in pairs, with the detector array dithered by 0.5 pixel between exposures in the pair, to ensure well-sampled final images. Multiple pairs are taken in a given visit to a field, and multiple visits are made to each field. The spectra have significant contributions from night sky emission and telluric absorption. We describe the APOGEE data reduction pipeline that takes the multiple visits of multiple pairs of data cubes and reduces them, including measurements of radial velocities for each visit, to final, calibrated, combined spectra. _

440.05 – Model Stellar Spectral Libraries for Analysis of the SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE)

Carlos Allende-Prieto[1, 16], Lars Koesterke[2], Matthew D. Shetrone[3], Olga Zamora[1, 16], Matthew P. Ruffoni[4], Verne V. Smith[5, 6], Katia M. Cunha[6, 7], James E. Lawler[8], Juliet C. Pickering[4], Gillian Nave[9], Ana Elia Garcia Perez[10], Dmitry Bizyaev[11], Bengt Edvardsson[12], Bengt Gustafsson[12], Bertrand Plez[13], Fiorella Castelli[14], Steven R. Majewski[10], Ricardo P. Schiavon[15], Szabolcs Meszaros[1, 16], Angel de Vicente[1, 16]

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The Apache Point Observatory Galactic Evolution Experiment (APOGEE) is obtaining high resolution (R~22,500), high signal-to-noise (> 100) spectra in the 1510-1690 nm spectral region for 100,000 cool, predominantly post-main sequence stars. To ascertain the stellar atmospheric parameters and measure chemical abundances for the numerous chemical elements with line transitions in this wavelength region, the APOGEE Atmospheric Parameters and Chemical Abundances Pipeline (ASPCAP) relies on an optimization algorithm that identifies the best-fitting model for each of the observed APOGEE spectra. The fitting algorithm speeds up the model evaluation by interpolation in pre-computed grids of synthetic spectra that have been compressed using Principal Component Analysis. Here we describe the main model grids used in ASPCAP for the tenth data release of the Sloan Digital Sky Survey (SDSS DR10), how they were calculated. We also provide a description of ongoing and planned upgrades.

440.06 – APOGEE-2: The Second Phase of the Apache Point Observatory Galactic Evolution Experiment in SDSS-IV

Jennifer Sobeck[2, 1], Steven Majewski[2], Fred Hearty[2], Ricardo P. Schiavon[6], Jon A. Holtzman[3], Jennifer Johnson[4], Peter M. Frinchaboy[5], Michael F. Skrutskie[2], Ricardo Munoz[9], Marc H. Pinsonneault[4], David L. Nidever[11], Gail Zasowski[16], Ana Elia Garcia Perez[2], Damian Fabbian[7, 8], Andres Meza Cofre[12], Katia M. Cunha[18], Verne V. Smith[14], Cristina Chiappini[10], Timothy C. Beers[14,]

[19], Matthias Steinmetz[10], Frederick Anders[10], Dmitry Bizyaev[15, 3], Alexandre Roman[17], Scott W. Fleming[13], Jeffrey D. Crane[20]

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Contributing teams: The SDSS-IV/APOGEE-2 Collaboration

The second phase of the Apache Point Observatory Galactic Evolution Experiment (APOGEE-2), a part of the Sloan Digital Sky Survey IV (SDSS-IV), will commence operations in 2014. APOGEE-2 represents a significant expansion over APOGEE-1, not only in the size of the stellar sample, but also in the coverage of the sky through observations in both the Northern and Southern Hemispheres. Observations on the 2.5m Sloan Foundation Telescope of the Apache Point Observatory (APOGEE-2N) will continue immediately after the conclusion of APOGEE-1, to be followed by observations with the 2.5m du Pont Telescope of the Las Campanas Observatory (APOGEE-2S) within three years. Over the six-year lifetime of the project, high resolution ($R\sim22,500$), high signal-to-noise (≥100) spectroscopic data in the H-band wavelength regime (1.51-1.69 µm) will be obtained for several hundred thousand stars, more than tripling the total APOGEE-1 sample. Accurate radial velocities and detailed chemical compositions will be generated for target stars in the main Galactic components (bulge, disk, and halo), open/globular clusters, and satellite dwarf galaxies. The spectroscopic follow-up program of Kepler targets with the APOGEE-2N instrument will be continued and expanded. APOGEE-2 will significantly extend and enhance the APOGEE-1 legacy of scientific contributions to understanding the origin and evolution of the elements, the assembly and formation history of galaxies like the Milky Way, and fundamental stellar astrophysics.

440.07 – The APOGEE Stellar Parameters and Chemical Abundances Pipeline (ASPCAP)

Ana Elia Garcia Perez[1], Carlos Allende-Prieto[2], Katia M. Cunha[3], Jon A. Holtzman[4], Jennifer Johnson[5], Steven Majewski[1], Szabolcs Meszaros[2], Ricardo P. Schiavon[6], Matthew D. Shetrone[7], Verne V. Smith[8]

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Contributing teams: The SDSS-III/APOGEE Collaboration

The Apache Point Observatory Galactic Evolution Experiment (APOGEE) of Sloan Digital Sky Survey III (SDSS-III) will be providing high quality (R ? 22,500 and a typical S/N > 100) near-infrared spectra for ~100,000, predominantly cool stars (mostly giant stars). In principle these spectra can be used to ascertain the stellar atmospheric parameters of those stars as well as the chemical abundances for approximately 15 chemical species expressed in the APOGEE wavelength region via both atomic and molecular line transitions. Detailed analysis of such an enormous database of infrared stellar spectra --- each blanketed with a multitude of lines and bands --- is obviously not viable manually, but is also a challenge to automate and simultaneously achieve the survey goals of high, 0.1 (0.2) dex internal (external) abundances precision. The APOGEE Stellar Parameters and Chemical Abundances Pipeline (ASPCAP) has been designed to estimate the above parameters via comparison to large, multi-dimensional libraries of synthetic spectral templates. To make the problem tractable and efficient, ASPCAP conducts this analysis in two phases. First the entire wavelength range is template-matched to derive the primary stellar parameters affecting the spectral energy distribution of the stars (Teff, log g, microturbulence, along with the bulk stellar metallicity and carbon, nitrogen and α-elements abundances). After an appropriate stellar template is matched or interpolated from the synthetic library, the abundances of other chemical species (e.g., C, N, O, Mg, Na, Al, Si, S, K, Ca, Ti, V, Mn, Cr, Co, Fe, and Ni) are derived using restricted windows around particularly sensitive atomic or molecular transitions. We will present an overview of ASPCAP, its calibration and measured performance, as evaluated with data from the first year of APOGEE observations as released in SDSS-III Data Release 10.

441 – Stars, Cool Dwarfs, Brown Dwarfs

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

441.01 – Accuracy of Astrometry Positions, Parallaxes, and Proper Motions

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Imaging cameras can deliver high signal-to-noise images that provide high precision astrometry. The limitations to accuracy usually depend on calibrations. This paper discusses current catalog and reference sources, and the level of accuracy that can be reached. Positions depend entirely on catalog accuracy that will improve dramatically with GAIA. Parallaxes and proper motions depend more on relative astrometry that is more precise - and can be very accurate. Measurements of QSOs made at the Naval Observatory are used to demonstrate that parallax accuracy levels of 0.2 mas and proper motion accuracy of 0.1 mas/yr can be routinely achieved.

441.02 – 20 Years of RECONS

Todd J. Henry[1]
1. RECONS, Atlanta, GA, United States.
Contributing teams: RECONS

RECONS (REsearch Consortium On Nearby Stars, www.recons.org) turns 20 in 2014, so we take this opportunity to review some of the highlights of the RECONS effort over the past two decades. Through comprehensive searches for new nearby stars, as well as characterization of the stars and exploration of their environments, the RECONS team has made significant contributions to our understanding of the solar neighborhood, and of our own place in the Universe. Here we highlight results detailed in more than 30 papers in The Solar Neighborhood series published in The Astronomical Journal, including: (1) a census indicating that at least 75% of all stars are red dwarfs, which have more real estate available for habitable planets than any other type of star, (2) more than 300 new stellar systems with accurate trigonometric parallaxes placing them within 25 pc, including 12 of the nearest 100 systems, (3) thousands of additional nearby star candidates identified through traditional proper motion searches and novel photometric searches for stars exhibiting minimal proper motions, (4) increases of more than 20% in the nearest white dwarf and cool subdwarf populations, (5) discovery of the nearest star, AP Col, younger than 100 million years, (6) knowledge that more than half of stellar systems contain only one star, dominated by the red dwarf multiplicity rate of only about 30%, (7) definition of the smallest main sequence star, with a radius only 9% that of the Sun (smaller than Jupiter) and a temperature of 2100K, and (8) a revelation that the smallest stars are rarely orbited by giant planets, including the elimination of planets down to half a Jupiter mass orbiting Proxima Centauri. As RECONS enters its third decade, we continue our reconnaissance of the solar neighborhood via a comprehensive survey to understand the nature of star formation by determining accurate luminosity and mass functions for the nearest stars. In addition, we are taking an inventory of nearby planets, including an astrometric search of several hundred of the nearest red dwarfs for planetary systems. This effort is supported by the NSF through grants AST-0908402 and AST-1109445, and via observations made possible by the SMARTS Consortium.

441.03 – Going the Distance: Parallaxes for SuperCOSMOS-RECONS (SCR) Stars

Jennifer G. Winters[2, 1], Sergio Dieterich[2, 1], Nigel C. Hambly[3, 2], Todd J. Henry[2, 1], Wei-Chun Jao[2, 1], John C. Lurie[4, 2], Adric R. Riedel[5, 2], John P. Subasavage[6, 2]
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Contributing teams: RECONS

We present trigonometric parallax measurements and VRI photometry for more than 100 newly discovered SuperCOSMOS-RECONS (SCR) systems in the southern sky. Thousands of new red dwarfs, white dwarfs, and cool subdwarfs were revealed via searches of the SuperCOSMOS electronic archives of photographic plates. The nearest of these are added to our RECONS (Research Consortium On Nearby Stars, www.recons.org) astrometry program at the CTIO/SMARTS 0.9m, now in its 15th year, which has ~500 nearby stars and brown dwarfs being observed for parallax at a given time. Trigonometric parallax is one of the most time-intensive, but accurate, methods of distance determination and is most reliable for nearby stars, allowing our solar neighbors to set the standard for the primary rung in the cosmic distance ladder. However, many of these neighbors, particularly the M dwarfs, remain hidden due to their intrinsic faintness and cause us to have an incomplete understanding of local stellar populations. Roughly two-thirds of the SCR stars observed have parallaxes placing them within 25 pc, constituting a significant contribution to the existing solar community and moving us closer to a comprehensive census of the solar neighborhood. Highlights among the discoveries are the six new red dwarf systems within 10 pc, five new white dwarfs within 25 pc, and six nearby systems with proper motions less than 100 mas/yr, a proper motion regime in which very

few nearby stars are known. Some of the SCR systems are compelling binaries containing unusual white dwarfs, very low mass stellar components, or degenerate brown dwarfs. We have valuable long-term datasets spanning more than a decade on many systems that allow us to search for unseen companions with masses as low as a few Jupiters. In sum, the SCR systems are crucial to our understanding of the stellar luminosity and mass functions in the Milky Way and beyond, provide key targets for astrophysical studies, and will be among the most important targets for future planet searches. This work is supported by AST-0908402 and AST-1109445, and via observations made possible by the SMARTS Consortium.

441.04 – Exploring The Wide Main Sequence of Low Mass Stars

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Contributing teams: RECONS Team

The RECONS (REsearch Consortium On Nearby Stars, www.recons.org) team has compiled photometric and astrometric data on over 3000 stars with trigonometric parallaxes placing them within 25 parsecs, allowing for an accurate representation of the H-R Diagram from A stars through M stars. We find that the main sequence is widest, by up to 2.5 full magnitudes in Mv, in the region of low mass K and M dwarf stars. This corresponds to a factor of almost 10 in luminosity among stars of the same temperature, but a detailed understanding of the causes of this range remains elusive. Given that temperature and radius determine the observed luminosity of a star, stars with identical temperatures must have radii differing by up to a factor of three to account for the width of the main sequence. In order to determine the underlying causes of the different radii, we have embarked on a project to measure the variability, rotation, ages, and metallicities of a large sample of the nearest low mass stars. We are comparing these stars to known young stars and cool subdwarfs in the same temperature slices to map the complex interplay of these many factors. Here we present our initial findings from the photometric variability data and first spectroscopic results. This effort is supported by the NSF through grants AST-0908402 and AST-1109445, and via observations made possible by the SMARTS Consortium.

441.05 – The Hydrogen Burning Limit

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Contributing teams: RECONS

We construct a Hertzsprung-Russell diagram for the stellar/substellar boundary based on a sample of 63 objects ranging in spectral type from M6V to L4. We report newly observed VRI photometry for all 63 objects and new trigonometric parallaxes for 37 objects. The remaining 26 objects have trigonometric parallaxes from the literature. We combine our optical photometry and trigonometric parallaxes with 2MASS and WISE photometry and employ a novel SED fitting algorithm to determine effective temperatures, bolometric luminosities, and radii. Our uncertainties range from 20-150K in temperature, 0.01-0.06 in log(L/Lsun), and 3-10% in radius. We check our methodology by comparing our calculated radii to radii directly measured via long baseline optical interferometry and find an excellent overall match with offsets generally less than 4%. We find evidence for the local minimum in the radius-temperature and radius-luminosity trends that signals the end of the stellar main sequence and the start of the brown dwarf sequence, at T~2075K, log(L/Lsun)~-3.9, and (R/Rsun)~0.086. The existence of this local minimum is predicted by evolutionary models, but at temperatures about 400K cooler. The minimum radius happens near the locus of 2MASS J0523-1403, an L2.5 dwarf with V-K=9.42. We compare and contrast the trends in our data to the predictions of several evolutionary models.This work is supported by NSF grants AST-0908402 and AST-1109445, as well as NASA/STScI grant HST-GO-12938.01-A, and via observations made possible by the SMARTS Consortium and at the SOAR telescope.

441.06 – A study of the wide, low-mass companion population with Pan-STARRS1

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Contributing teams: Pan-STARRS1 Builders

Wide low-mass companions to main sequence stars provide unique laboratories to study ultracool atmospheres, test models of star formation and develop new metallicity diagnostics. Using Pan-STARRS1's combination of multi-epoch data and wide

field of view, we have identified a large sample of low-mass, co-moving companions to Hipparcos stars ranging in spectral type from K7 to T4.5. Most of these were identified as part of a dedicated search for common proper motion companions closer than 10,000 AU. In addition we have added new L dwarf companions to M dwarfs both from a dedicated search for companions to nearby low-mass stars and serendipitously as part of our search for field brown dwarfs. In total we have over 60 companions and more than 20 L dwarf secondaries. This nearly doubles the number of wide (>300 AU), late M dwarf companions and represents an 80% increase in the number of L dwarf counterparts in the same separation range. We present these results and discuss how our final companion sample can be used to test substellar atmospheres and measure the separation and mass ratio distribution of the wide, low-mass companion population.

441.07 – Thirty-one new nearby binary systems discovered in archived Hubble Space Telescope images.

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We have searched the Hubble Legacy Archive for pictures that, deliberately or serendipitously, happen to include any one of 480,000 nearby main-sequence stars from the SUPERBLINK proper motion survey. The search has returned Hubble Space Telescope images for 823 stars with proper motions μ>40 mas/yr and apparent magnitudes V<20, all taken with either one of the WFPC2, NICMOS, ACS, or WFC3 cameras. The archived images were retrieved and analyzed to determine whether the stars appear single on the HST images or are resolved into visual pairs. Close examination has revealed 81 stars resolved in apparent close pairs. To rule out chance alignments with background sources, we have examined images of the same fields archived in the Digitized Sky Survey, and predating HST data by at least 40 year. In every case, we were able to rule out the possibility of a non co-moving companion, confirming that the pairs are gravitationally bound systems. A search of the Simbad database shows 50 of the systems to be previously identified binaries; the other 31 systems are reported here for the first time. All new systems consist of pairs of K and M dwarfs with distances between 50pc and 100pc from the Sun. (Based on research performed under a Cycle 18 Hubble Space Telescope archival program, with support from grant HST-AR-12124.01-A.)

441.08 – A Spitzer Survey for Wide Substellar Companions to Nearby Stars

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We have used multi-epoch images from the Spitzer Space Telescope to search for wide substellar companions to 135 nearby stars,white dwarfs, and brown dwarfs via common proper motions.This sample includes the recently discovered binary brown dwarf system WISE J104915.57-531906, which is the third closest known system to the Sun.Because of its proximity, our images are capable of detecting wide companions in that system down to the mass of Jupiter. We present the results of our imaging of WISE J104915.57-531906 and the other targets in our sample.

441.09 – Coronal heating of M dwarfs: The flare-energy distribution of fully convective stars

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Stochastic flaring is an important mechanism for the coronal heating of the Sun and solar-like stars. The driver for these flares is a magnetic dynamo anchored at the boundary layer between the convective zone and the radiative core. Fully convective M dwarfs have been observed to produce powerful flares as well, but they lack a radiative core and must possess a different dynamo mechanism. How their flaring behavior differs from the solar case is not fully understood yet. We have analyzed X-ray flares of 22 M dwarfs, including both fully and partially convective ones, using archival XMM-Newton data. We extracted flares from the individual X-ray light curves and determined the amount of energy released by each flare in the observed X-ray band. We constructed flare-energy distributions of the targets to investigate the degree to which flares heat stellar coronae. We fitted the slopes of the flare-energy distributions for individual targets and for groups of targets bundled by spectral type. Depending on the value of the slope, the total energy released by flares, as extrapolated from the flare-energy distributions, could be sufficient to heat the entire corona. We find that the slopes of the flare-energy distributions are very similar to that of the Sun, for both partially and fully convective M dwarfs. The dynamo process at work in the fully convective stars of our sample needs to have a flare production efficiency which is very close to the solar case. Further observations will cover ultracool targets near the brown dwarfs boundary to test for which masses this solar analogy is valid. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

441.10 – Magnetic Dynamos and X-ray Activity in Ultracool Dwarfs (UCDs): Constraining the Role of Rotation

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Although many fully-convective stars are magnetically active, the mechanisms by which they generate, sustain, and dissipate their magnetic fields are not well-understood. Observations suggest that empirical relations between X-ray activity, rotation, and radio emission evolve dramatically between the solar and ultracool dwarf (UCD; spectral types later than ~M6) regimes. The limited number of X-ray detections has prevented the drawing of firm conclusions, however. We combine new Chandra observations of seven late-M dwarfs with three previously-unpublished measurements from the Chandra archive and data from the literature to construct a database of 38 ultracool dwarfs with both X-ray and rotation measurements, the largest such catalog yet presented. We identify a substantial number of rapidly-rotating UCDs with X-ray activity as far as two orders of magnitude below the standard "saturation" level and find a significant anticorrelation between rotation and X-ray activity. We discuss several proposed "supersaturation" mechanisms that suggest a direct connection between faster rotation and suppression of X-ray activity and find many of them to be inconsistent with the data. We instead suggest the observed effect may be indirectly driven by a separate parameter correlated with both X-ray activity and rotation. The strength and topology of large-scale stellar magnetic fields have been found to vary widely within UCDs of similar stellar parameters. We speculate varying field topologies could explain the observed trends. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution. We also acknowledge support from the NSF through Grant AST-1008361 and from NASA through Chandra Award Number G02-13007A issued by the Chandra X-ray Observatory Center, operated by the Smithsonian Astrophysical Observatory and NASA under contract NAS8-03060.

441.11 – Magnetic Dynamos and X-Ray Activity in Ultracool Dwarfs (UCDs): Surprises in the Radio Band

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Radio observations established early on that some brown dwarfs host kilogauss magnetic fields, despite their low temperatures and the absence of the shearing tachocline that is believed to be key to the solar dynamo. The observed radio emission is often surprisingly bright, exceeding the standard magnetic radio/X-ray (Güdel-Benz) relation by as much as five orders of magnitude. This effect is still not satisfactorily explained. In an attempt to improve matters, we have constructed and analyzed a comprehensive database of ultracool dwarfs with both radio and X-ray data, including new observations of seven targets with *Chandra* and the upgraded VLA. While all of the newly-observed objects were detected in the X-ray, only one was detected in the radio. These new targets are thus consistent with the standard relation, in striking contrast with some previous data. Some pairs of dwarfs with outwardly similar characteristics (spectral type, $v \sin i$) have dramatically different emission properties, with radio/X-ray ratios that differ by two orders of magnitude. These results suggest that there is dramatic variance in ultracool magnetic activity. As we also discuss in a companion poster examining the relation between rotation and activity, variation in the topology of the magnetic field may explain the data. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution. We also acknowledge support from the NSF through Grant AST-1008361 and from NASA through Chandra Award Number G02-13007A issued by the Chandra X-ray Observatory Center, operated by the Smithsonian Astrophysical Observatory and NASA under contract NAS8-03060.

441.12 – Rotation Rates and other Physical Properties in a Sample of M-dwarfs from the Kepler Mission

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M-dwarf stars are the most common stars in the universe (80%) but also form the one of the least explored spectral classes. We analyzed a photometric sample of the 500 brightest M-dwarf star long-cadence lightcurves (T<4000K, logg>4) from the Kepler MAST catalogue for rotation rates of starspots and presence of flares. We determined (differential) rotation rates for a large fraction of the sample. We present the results of our survey M-dwarf rotation rates, starspot coverage, differential rotation rates, ages derived from the Age-Activity-Rotation relationship developed by Engle and Guinan (2011) as part of the Living with a Red Dwarf Program, and flare frequencies. We wish to acknowledge support from NSF/RUI grant #AST-1009903.

441.13 – Measuring the Rotational Velocities of Young M Stars

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We have measured the projected rotational velocities of 140 young M stars identified using ROSAT data and previously discussed in Shkolnik et al. 2009, 2012. Each stellar spectrum was fit with a specific spectral-type-matched, slowly rotating template spectrum to measure the projected rotational velocity, v sin i, for each star. Our preliminary analysis measured that 83% of the sample are rapid rotators, with vsini > 5 km/s. Unlike Reiners et al. 2012, who looked at old M stars, we do not see a strong correlation of more rapid rotation with later spectral type for the M0 through M4 stars. However our sample is all consistently younger, which may explain the higher percentage of rapid rotators. Many thanks to the National Science Foundation for their support through grant AST-1109693.

441.14 – Quantifying an Age-Activity Relation using Wide White Dwarf - M Dwarf Binary Pairs

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Due to the intrinsic faintness of M dwarfs (dM) and the lack of old (> 1 Gyr) nearby open clusters, traditional methods of tying spectroscopically derived properties such as activity to dMs of known ages are infeasible. However, binary systems represent ideal laboratories for investigating age-dependent relations since both components are thought to be coeval. Particularly useful are wide White dwarf+dM (WD+dM) binaries, in which precise WD ages (2040% uncertainty in total age) can be calculated using cooling models and detailed stellar evolution models. Previous studies have investigated age-activity relationships for isolated dMs, close WD+dM binary pairs, and wide WD+dM pairs. In each case, these studies were limited either by the age-dating methods used or the sample sizes. Our study addresses the deficiencies of prior studies by using a complete spectroscopic sample of wide WD+dM pairs; perfectly isolated coeval laboratories in which to further constrain the M dwarf age-activity relationship. We have compiled a sample of 250 high probability WD+dM pairs from existing common proper motion catalogs. At present, 50 of the pairs have had both components spectroscopically observed with either SDSS or the Perkins 1.83-m telescope at Lowell Observatory. Using our spectroscopic wide WD+dM sample, we relate the magnetic activity (as measured by H-alpha emission) to the WD ages (WD cooling times + progenitor lifetimes) in order to quantify an age-activity relation for M dwarfs with ages > 1 Gyr.

441.15 – A Color-Metallicity Relation for SDSS M Dwarfs

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We present a relation between the metallicities (derived from optical spectra) and colors of M dwarfs in the SDSS DR7 spectroscopic catalog. We also use wide, low-mass binaries to test the robustness of the spectroscopically derived metallicities. These relations have important ramifications for studies of Galactic chemical evolution, the search for exoplanets and subdwarfs, and are essential for surveys such as LSST, which do not have a spectroscopic component.

441.16 – SDSS M-dwarfs with WISE Signatures of Infrared Excess: Evidence of Warm Circumstellar Material in Low-Mass Field Populations

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Using dMs from the SDSS Data Release 7 spectroscopic catalog, we searched the WISE catalog to investigate the mid-infrared properties of cool field dwarfs. We developed SDSS and WISE color-color selection criteria to select 334 M dwarfs (~0.5% of the DR7 catalog) that show infrared excess above typical M dwarf photosphere levels at 12 and/or 22 μm. 80% of the stars in our sample are found at high Galactic latitudes (|b| > 20°) but close to the Galactic plane (87% with |Z| < 200 pc). We also find 63 stars in close proximity to the Orion complex that have not been previously identified. We perform synthetic photometry and characterize the dust populations inferred from each infrared excess. We also investigate the possibility that these infrared excesses could arise from ultracool binary companions by modeling combined dM+ultracool companion binary spectral energy distributions from theoretical tracks. We find that none of our stars show IR excesses consistent with ultracool companions at the 3? level. From the SDSS spectra we measure surface gravity dependent features (K, Na, and the CaH3 index), and examine tracers of youth (Hα, UV emission, and Li absorption). We find that less than 6% of our sample shows a reliable indication of youth, implying that we are likely probing an older population of field stars (>1 Gyr). We estimate UVW space motions, and find the majority of stars exhibit kinematics expected of disk stars, with the

exception of four stars that exhibit extremely high velocities (total velocity > 400 km/s). Lastly, we study the fraction of low-mass stars exhibiting infrared excess as a function of Galactic height and find the fraction of dMs with excesses quickly declines past |Z| > 200 pc., and that earlier spectral types have a higher disk fraction close to the Galactic plane than later spectral types, supporting the notion of mass and age dependent disk evolution. This sample indicates that disks may persist for timescales much longer than previously thought, possibly due to longer disk lifetimes around low-mass stars. Other possible explanations for the IR excesses include tidal disruption of planetary bodies or failed planet formation.

441.17 – Photometric and Spectral Analysis of Blue and Red L Dwarfs

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L dwarfs have a range of near-infrared colors at a given optically-defined spectral subtype, which is variously attributed to differences in gravity, metallicity, and dust/cloud properties. For a limited number of these objects, diagnostic spectral features indicate low surface gravity (red, young objects) or low metallicity (blue, subdwarfs), but for most of the objects the cause of the extreme color is unknown. We explore the photometric and spectral features of color outliers using multi-resolution near-infrared spectra, WISE mid-infrared photometry, parallaxes, and kinematics to explore underlying physical and atmospheric properties. The analysis is anchored by optical spectra (as a proxy for effective temperature) and benchmarks such as confirmed young objects, subdwarfs, and companions. This is the largest, most diverse observational dataset of red and blue L dwarfs assembled to date.

441.18 – Spectral Variability and Cloud Structure in Luhman 16AB

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We report resolved near-infrared spectroscopic monitoring observations of the nearby L dwarf/T dwarf binary WISE J104915.57-531906.1AB (aka Luhman 16AB), as part of a broader campaign to characterize the spectral energy distribution and temporal variability of this source. A continuous 45-minute sequence of low-resolution spectra spanning 0.8-2.4 μm was obtained with IRTF/SpeX, concurrent with combined-light optical photometry with TRAPPIST. Our integrated spectral observations confirm the flux reversal of this binary, with the T dwarf secondary being brighter from 0.8-1.5 μm. We observe a wavelength-dependent decline in the relative fluxes of the two components over the course of the observation, concurrent with a decline in the optical brightness of the combined light system, variations that can be successfully modeled with both achromatic (brightness) and chromatic (color) variations in Luhman~16B, assuming Luhman~16A to be nonvariable. We estimate a peak-to-peak amplitude of 13.5% at 1.25 μm over the full lightcurve, intermediate in amplitude and period as the variable early-T dwarfs SIMP 0136+0933 and 2MASS J2139+0220 confirm the correlation suggested by Apai et al. assuming spot sizes are set by the atmospheric Rhines scale. Using a simple two-layer brightness-temperature model, we infer a cloud coverage fraction of 33--57% than varies by up to 50% assuming a 300 K difference between cool cloud tops and hot "holes". The strong variability of Luhman 16B combined with the relative spectral intensities of the A and B components support the model of a patchy disruption of the mineral cloud layer across the L dwarf/T dwarf transition.

441.19 – A Volume-Limited Search for L/T Transition Brown Dwarfs With the Pan-STARRS and *WISE* Surveys

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We are conducting a productive wide-field (30,000 deg^2) search for brown dwarfs in the L/T transition (spectral types ? L6-T5) within 25 pc using the Pan-STARRS1 (PS1) 3? and *WISE* all-sky surveys. Previous large-scale searches have been incomplete for L/T transition dwarfs because these objects are faint in optical bands and have near-infrared colors that are difficult to distinguish from background stars. To overcome these obstacles, we have cross-matched the PS1 (optical) and *WISE* (mid-IR) catalogs to produce a unique multi-wavelength database for finding ultracool dwarfs. We have so far discovered over 80 new L/T transition dwarfs in 3/4 of our search area, 28 of which lie within 25 pc. We have also made several serendipitous discoveries of field L dwarfs showing extreme cloud-induced reddening and/or spectroscopic signatures of youth. We are identifying a well-defined, volume-limited sample of dozens of late L and early T dwarfs, which will be used

to better understand and model the evolution of brown dwarfs through the L/T transition.

441.21 – A Survey of L/T-transition and Peculiar Brown Dwarfs from an SDSS/2MASS/WISE Cross-match

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We are studying a broad sample of brown dwarfs that are either in the process of sedimenting dust from their atmospheres, or have peculiar atmospheric characteristics, such as low surface gravities, metallicities, or unusual cloud properties. Our study has uncovered 25 candidate peculiar early L- to early T- dwarfs which are mostly completely new objects with only a few having been previously discovered but with no published spectra. With spectroscopic observations, we confirmed that 12 from our prioritized sample and one from our complete sample, are moderately peculiar or are potentially L/T binaries, including one which, with a J-Ks color of 2.62, is the reddest field dwarf currently known. These new discoveries come from the SDSS, 2MASS and WISE surveys which have already been subject to considerable scrutiny, demonstrating that our exploration of these surveys is not yet complete. The ultimate goal of this program is to produce a flux-complete estimate of the fraction of peculiar ultra-cool dwarfs in large-area surveys and improve our ability to classify these objects on a more finely gradated classification scheme.

441.22 – Photometric Variability of Y Dwarfs

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Condensate clouds are present in brown dwarf atmospheres due to their low surface temperatures. As the coolest (Teff < 600 K) class of brown dwarfs currently known, Y dwarfs allow us to study the unique atmospheric physics that occur at these temperatures including the formation of sulfide, chloride, and water clouds. Dynamic inhomogeneities in cloud cover should manifest as photometric variabilities in the observed light curves of brown dwarfs. This phenomenon was originally documented in two brown-dwarfs by Morales-Calderón et al. (2006) at 4.5 microns, and in one brown dwarf by Heinze et al. (2013) at 3.6 microns. We describe our ongoing program to monitor fourteen Y dwarfs for photometric variability at 3.6 and 4.5 microns with the Spitzer Space Telescope and present initial results including the first detection of Y dwarf variability.

441.23 – A USNO Search for Astrometric Companions to Brown Dwarfs IV

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Preliminary analyses of ten brown dwarfs observed by the U.S. Naval Observatory infrared parallax program show no clear indication of astrometric perturbations due to low mass companions. The data were collected using ASTROCAM on the 1.55-m (61-in) Kaj Strand Astrometric Reflector from 2000 September through 2006 June over periods from 2.0 to 5.3 years. After our standard solution for parallax and proper motion, the residuals were subjected to a time-series analysis using the Lomb-Scargle periodogram method. The multiplicity fraction for brown dwarfs constrains theories of brown dwarf formation and evolution. Binary systems, especially those that straddle the transition between L and T spectral types, are also significant tests of atmospheric models. In addition, the identification of companions would have enabled the eventual measurement of the associated masses. This search for astrometric companions is an extension of the initial infrared parallax program. When finalized, the trigonometric parallaxes for these brown dwarfs will provide accurate distances for use in determining their luminosities and temperatures. The brown dwarfs in this subsample have spectral types that range from late M through mid-T. None of them are known binaries. Distance estimates place six of these objects within the 25-pc limit of the Solar Neighborhood, and preliminary parallaxes place another three between 25 and 35 pc. These substellar objects are located north of -15° Dec. The brown dwarfs evaluated are 2MASS J00325937+1410371, 2MASS J01514155+1244300 (BF Ari) 2MASS J02074284+0000564, 2MASS J03095345-0753156, SDSS J083717.21-000018.0, 2MASS J11101001+0116130, 2MASS J13262981-0038314 (2MUCD 11143), 2MASS J17502385+4222373, 2MASS J23391025+1352284, and 2MASS J23565477-1553111. Analyses of another 30 brown dwarfs were presented earlier and the analyses of 19 more brown dwarfs are planned.

441.24 – New Evidence for a Substellar Luminosity Problem

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HD 130948BC was the first field brown dwarf system to have both a dynamically measured mass and precise age constraint, from its solar-type host star, and it was unexpectedly ?2× more luminous than predicted by substellar evolutionary models. However, because of the difficulty in determining accurate stellar ages, even in this nearly ideal case of a young star where numerous age indicators agree, it has been unclear if the apparent over-luminosity could be due to an erroneous age for this unique system. If such large systematic errors actually exist in substellar evolutionary models it could have wide-ranging implications, from determinations of the initial mass function to the masses estimated for directly imaged planets. We present here a new dynamical mass for a pair of brown dwarfs that also have a well-determined age from their young, solar-type star. This first check on the substellar "luminosity problem" reveals a nearly identical systematic error as was previously observed. We compare predictions from commonly used evolutionary models and present possible explanations for this problem. There are little appreciated, large differences (?0.2 dex) in the predicted luminosity evolution of substellar objects which, along with the discrepancies of models compared to observations, currently limit our ability to characterize the fundamental properties of both brown dwarfs and directly imaged exoplanets.

441.25 – Spectral Energy Distributions as Photometric and Spectroscopic Probes of Brown Dwarf Atmospheres

Joe Filippazzo[1, 2], Emily L. Rice[2, 3], Kelle L. Cruz[4, 3], Jacqueline K. Faherty[3, 5]
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Contributing teams: BDNYC

Physical parameters such as effective temperature, surface gravity, metallicity, and dust and clouds muddle the characteristics of brown dwarf atmospheres. To disentangle the effects of these components we construct nearly complete absolute spectral energy distributions (SEDs) for a large sample of brown dwarfs by combining SDSS, 2MASS, IRAC and WISE photometry with our extensive database of optical and near-infrared spectra and parallaxes. We fit PHOENIX model atmospheres to the SEDs to constrain radii and calculate bolometric luminosities for comparison of objects with the same spectral type. We also use model atmospheres to identify colors indicative of youth and compare to our sample of brown dwarf SEDs using both survey and synthetic photometry. Our extended SEDs provide a powerful spectroscopic and photometric tool for characterizing the atmospheres of brown dwarfs and identifying new young candidates.

441.26 – Microlensing as a New Tool for Measuring the Masses of Nearby Brown Dwarfs

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A key parameter in comparing known brown dwarfs to model calculations is knowing the mass of the observed object. Although binary brown dwarfs can be used to determine masses using Kepler's Laws, we are trying a novel approach to measure the mass - by identifying brown dwarfs that have a high probability of microlensing a background object in the near future. To do this we will search for brown dwarfs with high proper motion along the galactic plane where the source density for background objects is very high. Looking for brown dwarfs with high proper motion in this region of space will increase the probability of microlensing events. To ensure that these brown dwarfs are in motion we have analyzed images from two infrared surveys, specifically the Two Micron All Sky Survey (2MASS) and Wide-Field Infrared Survey Explorer (WISE) with an epoch difference of ~10 years. This allows us to determine a tentative trajectory and an estimate of when the brown dwarf will microlens a background object in its path. In this poster we will update our progress on identifying such candidate brown dwarf microlensers.

441.27 – A Proper Motion Census of Ophiuchus

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The motivation for this survey is to discover new objects not detected by previous photometric surveys; objects such as disk-less (Class III) objects, brown dwarfs, and very low luminosity objects. We use proper motion to determine whether or

not objects are members of Ophiuchus and therein complete a census of the region. We use Spitzer/IRAC images from two epochs (2004 and 2013) to establish which objects have moved and how far with respect to the background stars. The reported motion of Ophiuchus is ~29 milliarcseconds per year, which is difficult to detect because the IRAC plate scale is large (1,223 milliarcseconds/pixel). Since Spitzer/IRAC is very stable, we should be able to detect very small motions of objects. The limit on astrometric precision to date has been the default 3rd order IRAC distortion solution. We created a 5th order distortion solution which improves the astrometric noise floor from ~0.2 arcseconds to ~0.02 arcseconds at each epoch. With it we have been able to decrease errors in the positions of detections to under 75 milliarcseconds per image in both the 2004 data and 2013 data. This allows us to identify candidate Ophiuchus members with high statistical significance.

441.28 – Searching for Local Evidence of Supernova Enrichment in the Scorpius Centaurus OB Association

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Can we detect and model enrichment within a star-forming complex with a well-constrained star-formation history, kinematics and membership? The proximity of the Scorpius-Centaurus OB Association (hereafter Sco-Cen) makes it an ideal target for answering this question. Using a Salpeter IMF and a total inferred mass for Sco-Cen subgroups, approximately one dozen supernovae are expected to have occurred within the two oldest subgroups (UCL and LCC), potentially enriching the slightly younger Upper Sco subgroup. In this work we present updated abundances of intermediate mass elements (O, Na, Mg, Si, S, Al, Ca and Ti) in relation to Fe-peak elements to quantify core collapse supernova enrichment between the subgroups. The results are derived based on high-resolution (R~60000), high S/N (S/N~200-400) spectra from the Magellan MIKE spectrograph. In addition to discussing the implications of these results on our understanding of small-scale supernova chemical evolution we briefly explore the presence of NLTE overionization/overexcitation effects in our stellar sample.

441.29 – Spectroscopic Observations of Nearby Low Mass Stars

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Young low-mass stars are known to be bright in X-ray and UV due to a high level of magnetic activity. By cross-correlating the GALEX Catalog with the WISE and 2MASS Point Source Catalogs, we have identified more than 2,000 stars whose UV excesses suggest ages in the 10-100 Myr range. We used the Shane 3-m telescope at Lick Observatory on Mount Hamilton, California to observe some of these 2,000 stars spectroscopically. We measured the equivalent width of lithium at 6708 A absorption and H-alpha emission lines. Out of a total of 122 stars observed with the Kast grating spectrometer, we find that roughly 10% have strong lithium absorption features. The high percentage of stars with lithium present is further evidence of the importance of UV emission as a youth indicator for low-mass stars. In addition, we used high-resolution spectra obtained with the Hamilton echelle spectrograph to determine radial velocities for several UV-bright stars. These radial velocities will be useful for the calculation of Galactic UVW space velocities for determination of possible moving group membership. This work is supported by NASA Astrophysics Data Analysis Program award NNX12AH37G to RIT and UCLA and Chilean FONDECYT grant 3130520 to Universidad de Chile. This submission presents work for the GALNYSS project and should be linked to abstracts submitted by David Rodriguez, Laura Vican, and Joel Kastner.

441.30 – Serendipitous Chandra X-ray Spectroscopy of GALEX Nearby Young-Star Survey (GALNYSS) Candidates

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More than 2000 candidate young (age 10-100 Myr) low-mass stars within ~100 pc of Earth have been identified by the Galex Nearby Young-Star Survey (GALNYSS), via the combination of ultraviolet (Galex) and near-IR (WISE and 2MASS) photometry and kinematic data. Among these candidates, we find more than a dozen objects for which serendipitous archival Chandra X-ray observations are available. The spectral types for these objects, if stellar, range from early- to mid-M. Hence, this serendipitously observed subsample affords the opportunity to study the X-ray emission characteristics of young stars at the low-mass end of the stellar mass spectrum. We present preliminary results of spectral analysis, including estimates of plasma temperature, intervening absorption, and intrinsic X-ray luminosities, for these Chandra X-ray counterparts to GALNYSS candidates. These results will be used both to confirm young, late-type star status and to investigate the evolution of magnetic (coronal) activity in stars whose masses potentially range from a few tenths of a solar mass down to near the H-burning limit. This work is supported by NASA Astrophysics Data Analysis Program award NNX12AH37G to RIT and UCLA and Chilean FONDECYT grant 3130520 to Universidad de Chile.

441.31 – Insights on Li Depletion from the Oldest Solar Twin HIP 102152

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We present detailed chemical abundance analyses of the oldest solar twin HIP 102152, with a derived age of 8.2 Gyr, and the younger 2.9 Gyr solar twin 18 Sco. We determined differential abundances of 21 elements relative to the Sun with precisions as high as 0.004 dex, using ultra high-resolution (R = 110,000), high S/N (~500-1000) UVES spectra obtained on the 8.2-m VLT, covering 4800-10,000 Å. The metallicity of HIP 102152 was found to be [Fe/H] = -0.013 ± 0.004, with an effective temperature that is 54 K cooler than the Sun, 0.09 dex lower in surface gravity, and a microturbulence identical to our derived solar value. Elemental abundance ratios examined vs. dust condensation temperature reveal a solar abundance pattern for this star, in contrast to most solar twins, such as 18 Sco. Deficiencies in refractory elements relative to volatile elements, like those observed in HIP 102152, may be suggestive of a depletion of refractory elements during the planetesimal accretion phrase, which may be a tell-tale sign of rocky planet formation. The solar chemical pattern of HIP 102152 thus makes it a potential candidate to host terrestrial planets, which is reinforced by the lack of giant planets in its terrestrial planet region. We also report NLTE Li abundances for the two solar twins and the Sun. The Li abundance of HIP 102152, log ε (Li) = 0.48 ± 0.07, is the lowest reported to date for a solar twin, and allows us to consider an emerging, tightly constrained Li-age trend for solar twin stars.

441.32 – Rapidly Rotating Red Giants in APOGEE

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The Apache Point Galactic Evolution Experiment (APOGEE) provides a unique possibility to study a large number of stars in all parts of the Milky Way via high resolution NIR spectroscopy. Most of about fifty thousand APOGEE spectra released in DR10 of SDSS-III belong to red giants. A small fraction of relatively cool red giants indicate unusually rapid surface rotation (Vsini > 10 km/s). APOGEE's combination of high resolution and high signal-to-noise ratio allows us to study the stellar rotation for a large sample of cool stars. We present a catalog of a few hundred rapidly rotating cool red giants (RRCRG) and discuss best technique for estimating the vsini parameter from APOGEE spectra. We compare our vsini values with published Kepler data and with optical spectroscopy. Using precision Kepler surface gravities available for a few thousand APOGEE giants, we show that most of selected rapid rotators are reg clump giants, although we see examples of RRCRG at other evolutionary stages.

441.33 – The PTI Giant Star Angular Size Survey: Effective Temperatures & Linear Radii

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We report new interferometric angular diameter observations of over 200 giant stars observed with the Palomar Testbed Interferometer (PTI). These angular diameters are combined with bolometric fluxes derived from detailed spectral energy distribution (SED) fits, to produce robust estimates of effective temperature (T_EFF). These SED fits include reddening estimates and are based upon fits of empirical spectral templates to literature photometry, and narrow-band photometry obtained at the Lowell 31" telescope. Over the range from G5III to M8III, T_EFF estimates are precise to 50K per spectral type. Radius estimates are limited by the improved Hipparcos estimates of van Leeuwen (2007) and are typically ~10% per star.

441.34 – Chemical Abundances in Exoplanet Host Stars

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Stars that host exoplanets are a valuable tool for understanding and constraining planet formation environments. In order to

explore this we analyzed high-resolution stellar spectra of a sample of 8 exoplanet host stars. We perform a standard excitation/ionization analysis to determine temperature, surface gravity, microturbulent velocity and metallicity in each star. In addition, we have found abundances of a variety of refractory and volatile elements for comparison to stars without known planets. We present the abundances of these exoplanet hosts and compare them to results from previous high-resolution exoplanet host studies.

441.35 – Mapping small-scale starspots on Kepler transiting planet host stars

Leslie Hebb[1, 2], James R. Davenport[2], Suzanne L. Hawley[2], Moira M. Jardine[3], Joseph Llama[3]
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High precision, near-continuous time series photometry of large numbers of transiting planet host stars is now available from the Kepler satellite archive. Using short cadence light curves of transiting planet host stars with sub-millimag photometric precision we are now, for the first time, able to map relative brightness variations due to small-scale starspots on the surfaces of stars other than the Sun. Here, we present a new project whose goal is to derive the detailed time evolution of the starspot distribution on the surface of tens of stars with a range of masses and rotation rates. We have developed an eclipse mapping code which we are using to determine the lifetime of individual starspots and starspot groups by identifying and modeling brightness variations during planetary transits caused by the planet crossing in front of a starspot on the stellar surface. In order to reduce the degeneracy of the light curve inversion problem, we are using precise knowledge of the planet's position and comprehensively modeling the in- and out- of transit data to strengthen the constraints on the positions of the surface spots. Here, we describe our overall project, explain our eclipse mapping technique in detail, and present preliminary results on the transiting planet host star, Kepler-17. Preliminary results on the spot evolution of additional systems (Kepler-17, Kepler-63, HAT-P-11, and GJ1243) are presented in a corresponding presentation by J.R.A. Davenport.

441.36 – A Spitzer Search for Substellar Companions of Nearby Planet-Host Stars

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Perturbations by widely separated substellar-mass companions through the Kozai-mechanism has been invoked to explain the high mean eccentricity of exoplanets. We have conducted an imaging search for substellar-mass companions within 25-300 AU of 14 nearby (<15pc) planet-host stars, using the Spitzer/Infrared Array Camera (IRAC) at 3.6 and 4.5µm. We present candidate companions found to have brown-dwarf-like colors or color limits, and provide model-based upper mass limits for unseen objects in each field. We also discuss the methods we have developed for this project for point-spread-function subtraction and artifact removal of IRAC subarray images.

441.37 – WISE colors of the MK spectral standard stars.

Babar Ali[1]
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I present photometry and colors of well-established MK spectral standard stars using the WISE all-sky survey data. The spectral standard stars are taken from the compilations of Garrison (1986), Gray (2003, 2006) and the Michigan Spectral Atlas. I present the algorithm used to predict the star's position at the epoch of WISE observation. The collected photometry was examined and corrected for the expected excess emission at WISE wavelengths. The overall motivation is driven by predicting YSO colors using Spitzer/WISE and Herschel photometry.

441.38 – New GALEX UV Data Products At MAST For Stellar Astrophysics

Bernie Shiao[1], Scott W. Fleming[1], Chase Million[2], Mark Seibert[3], Luciana Bianchi[4], Randy Thompson[1], Shui-Ay Tseng[1], William J. Adler[5], Min Hubbard[6], Karen Levay[1], Barry F. Madore[3], Christopher D. Martin[6], Maria A. Nieto-Santisteban[1], Raghvendra Sahai[5], David Schiminovich[7], Richard L. White[1], Ted K. Wyder[8]
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The Galaxy Evolution Explorer (GALEX) mission ended in June 2013 after ten years in orbit. Its FUV and NUV microchannel

plate detectors were used to conduct a variety of direct imaging and spectroscopic astronomical surveys with various depths and sky coverage, recording individual photon events with a time resolution of five thousandths of a second. Although the mission has ended, MAST is continuing to provide new data products as the mission transitions to a legacy archive. One product is the GCAT (Seibert et al., in prep), a catalog of GALEX sources across the entire GR6 data release that removes duplicate objects found in the GALEX MCAT. The GCAT defines "primary" NUV and FUV fluxes within the AIS and MIS surveys (~40 million and 22 million sources, respectively), accounting for tile overlaps, and with visual inspection of every tile to flag artifacts and conduct other quality control checks. Another catalog of unique sources is that of Bianchi et al. (2013). Similar to the GCAT, their catalog produces a list of distinct GALEX sources in both the FUV and NUV from the AIS and MIS surveys, and includes data from GR7 (through the end of 2012). They have also cross-matched their sources with SDSS DR9, GSC-II, PanSTARRS, and 2MASS. We review access options for these catalogs, including updated matches between the GCAT and SDSS / Kepler available at MAST. In addition to these unique GALEX source catalogs, MAST will provide a database and software package that archives each of the ~1.5 trillion photon events detected over the lifetime of the mission. For the first time, users will be able to create calibrated lightcurves, intensity maps, and animated movies from any set of photons selected across any tile, and with specified aperture sizes, coordinates, and time steps. Users can access the data using either a python-based command-line software package, through a web interface at MAST, or (eventually) through CasJobs using direct SQL queries. We present some example GALEX lightcurves and images using this new data product to highlight just some of the possibilities available for users to mine the GALEX photon database, particularly with variable sources.

441.39 – New Kepler Data Products At MAST For Stellar Astrophysics

Scott W. Fleming[1], Bernie Shiao[1], Shui-Ay Tseng[1], Chase Million[2], Randy Thompson[1], Mark Seibert[3], Faith Abney[1], Tom Donaldson[1], Theresa Dower[1], Dorothy A. Fraquelli[1], Steven Handy[1], Anton M. Koekemoer[1], Karen Levay[1], Jacob Matuskey[1], Brian McLean[1], Lee Quick[1], Anthony Rogers[1], Geoff Wallace[1], Richard L. White[1]
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The Kepler Mission has collected high-precision, time-series photometry of over 200,000 stars. The reduced lightcurves, target pixel files, and a variety of catalog metadata are already available at MAST. We present new data products and services at MAST that will further aid researchers as Kepler begins its transition to a legacy mission, particularly in the realm of stellar astrophysics. New photometric catalogs to accompany the Kepler targets have arrived at MAST within the past year, and several more will be coming in the relative future. These include the second half of the Kepler INT survey (U,g,r,i,H_alpha; available now), an improved GALEX source catalog (NUV and FUV; available now), PanSTARRS (g,r,i,z; available soon), and WISE (3.4, 4.6, 12, and 22 microns; planned). We expect searches for variability will become one of the most active areas of archive use, so MAST is including a wide range of variability statistics as part of the archive database. In addition to being searchable through database queries and web forms, each Preview page will now include a summary of these variability indices for each of the target's lightcurves within a Quarter. Along with updated NUV and FUV fluxes, a new tool at MAST called gPhoton will allow users to create time-series lightcurves, including animated movies and intensity images, from any set of GALEX photons with arbitrary aperture and bin sizes. We show some examples of the ways GALEX UV lightcurves generated with gPhoton can be used in conjunction with the Kepler data. Finally, MAST has released an initial version of its Data Discovery Portal. This one-stop, interactive web application gives users the ability to search and access data from any of MAST's missions (HST, GALEX, Kepler, FUSE, IUE, JWST, etc.), as well as any data available through the Virtual Observatory. It includes filtering options, access to interactive displays, an accompanying AstroViewer with data footprints on-sky, the ability to upload your own catalogs, and cross-match functionality. We highlight a few of these capabilities in the specific context of Kepler.

441.40 – Double the Lightcurves, Double the Fun: Stellar Activity on the M Dwarfs GJ 1245 A and B with Kepler

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GJ 1245ABC is a nearby triple system comprised of two M5 components (A and B) and a very low mass stellar companion (C) to A. As a Kepler target, this system presents a unique opportunity to study the stellar activity of two coeval, nearly-equal mass M dwarfs. Components AC and B are separated by 7". Given Kepler's large plate scale of 4"/pixel, this system is not resolved in the Kepler pipeline processing. Time series analysis reveals two strong periodic signals due to starspots on components A and B, which have different rotation periods. The C component is ~3 magnitudes fainter than A, and as such does not contribute significantly to the flux from A. Examining the Kepler pixel files directly, we are able to use these periodic signals to disentangle the A and B components. Here we demonstrate this novel technique, and present preliminary separated lightcurves for GJ 1245 A and B. Ultimately, we will determine the individual flare occurrence rates for A and B, providing an important test for stellar age-activity-rotation models.

442 – Star Associations, Star Clusters - Galactic & Extra-galactic Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

442.01 – The Discovery of an Extreme Molecular Super Star Cluster Precursor with ALMA

Kelsey E. Johnson[1,2], Crystal L. Brogan[2], Rupali Chandar[4], Aaron S. Evans[1,2], John E. Hibbard[2], Adam K. Leroy[2], Kartik Sheth[2], Bradley C. Whitmore[3]
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Observationally constraining the physical conditions that give rise to massive star clusters has been a long-standing challenge. Now with the ALMA Observatory coming on-line, we can finally begin to probe the birth environments of massive clusters. Our team's Cycle 0 observations of the Antennae Galaxies reveal the molecular clouds in this prototypical starburst in unprecedented detail. Among the exciting findings is the discovery of the first known example of the molecular precursor to a super star cluster. We identified this proto-cluster as a compact CO(3-2) cloud with an exceptionally large line-width. This CO cloud (which our team began colloquially referring to as the "firecracker") has no associated Paβ or thermal radio emission, indicating that star formation has not yet begun -- this allows us to assess the physical conditions *before* the onset of star formation. The observed CO(3-2) intensity and size of the cloud imply a mass of at least 10^7 M™ and a surface density on 50 pc size scales of nearly 1 g/cm^2. Along with the CO(3-2) linewidth, the observed properties indicate that this cloud appears to be subject to remarkable external pressure (potentially as high as $P/k \sim 10^8$ K cm^{-3}). A comparison with ALMA CO(2-1) science verification observations and non-LTE analysis yields an excitation temperature of ~25K; an equilibrium state would require significant internal nonthermal pressure.

442.02 – Characterizing the AB Doradus Moving Group Using High Resolution Spectroscopy and Kinematic Traceback

Kyle McCarthy[1], Ronald J. Wilhelm[1]
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We present a detailed analysis on 10 proposed F and G members of the nearby, young moving group AB Doradus (ABD). ABD is at an interesting point in stellar evolution where the F and G members have inflated surface gravities (log(g) ~ 4.55) and lower vsin(i) (< 20 km/s) compared to other nearby moving groups (e.g. β Pictoris, Tucana-Horologium, Columba). The result is a large sample of well behaved (no vieling, non-LTE effects, blending from rotation), young stars which provide meaningful insights for stellar and planetary formation. Our sample was obtained using the 2.7m telescope at the McDonald Observatory with the 2dcoudé echelle spectrograph, achieving a resolving power over 60,000 with S/N ~ 200. We derive spectroscopic T_{eff}, log(g), [Fe/H], and microturbulance using a combination of the TGVIT and MOOG software with Kurucz Atlas 9 models and implement ionization and excitation balance. Characterization of the ABD sample is performed in three ways: (1) Chemical homogeneity, (2) Isochrone agreement, and (3) Kinematic Traceback. To investigate chemical homogeneity, we measure the abundances of 10 elements (not including iron) using the abfind package in MOOG. Isochrones are measured by plotting our sample on top of several evolutionary models on the HR Diagram. Finally, we use a kinematic traceback to map the trajectory of these stars back in time to the estimated epoch of formation (125 Myr). In our sample of 10 stars, we identify 1 star which is a probable non-member, 3 stars which have questionable membership, and 6 confirmed members.

442.03 – Deep Seven-color Photometry and Classification of Stars in the Cyg OB2 Association

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1. Vatican Observatory, Castelgandolfo, Holy See (Vatican City State). 2. Ignatianum College, Cracow, Poland. 3. Vilnius University, Vilnius, Lithuania.

A few years ago Drew et al. (MNRAS, 386, 1761, 2008) in the vicinity of the Cyg OB2 association have found hundreds of A0-A5 stars, applying the three-color IPHAS photometric system. The estimated distances to these early A-stars are close to the distance of Cyg OB2. If they belong to the association, this means that the star forming process in the association is non-coeval. To verify the reddenings, spectral types, distances and ages of the discovered A-type stars, we have started their investigation in the Vilnius seven-color system which gives MK classification and reddening determination of stars of all spectral types. Therefore, together with the supposed early A-stars, we will classify hundreds of stars down to V = 18 mag or fainter, and this will allow us to estimate distances to the Great Cygnus Rift and to the Cygnus X star forming region. In the poster we will present the preliminary results of photometry and classification of stars in three 13x13 arcmin areas close to the center of Cyg OB2.

442.04 – Searching for Stellar Sub-Structure in the Galactic Bulge

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We have discovered a group of 7 bulge giants with radial velocities of +300 km/s in a two degree field toward the Galactic bulge at (l,b) = (-6,-8). They are separated from the highest velocity bulge members by ~100 km/s. Recently, ARGOS reported a group of 4 kinematically distinct metal-poor bulge stars in their l = -20 fields. Coincidentally, these stars have radial velocities of +300 km/s. Given the scarcity of stars with velocities of +300 km/s in the Bulge, these stellar features may be related and part of a large independent stream or moving group in the inner Galaxy. We present preliminary results of high-resolution spectroscopy of 4 BRAVA stars with 300 km/s at (l, b) = (-6°,-8°) and 2 RAVE stars with 300 km/s at (l, b) = (-12°,-15°), taken with the MIKE spectrograph on the 6.5m Magellan telescope. The detailed abundance signatures provide an understanding as to the extent of this 300 km/s stellar system and a discussion on this potential newly discovered bulge stream.

442.05 – Moving group or cluster members?

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A moving group has been identified in "Selected Area 57" with observed velocity dispersion of ~0.27 km s-1 which lie within a circle of radius 0.5° on the sky. The W11450 group (Latham I) have distances consistent with all stars being within 2 pc of each other. Our aim is to test the chemical homogeneity of the star association using high resolution stellar spectroscopy to determine whether this group may share a common star formation history.

442.06 – Is Loden 1 an old and nearby star cluster?

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In 1980, L O Loden discovered a loose stellar cluster in the southern Milky Way, which he described as an "evident concentration of [17] late-type stars in the Field 1 - and main-sequence A-F stars not confirmed but strongly suspected." Kharchenko et al. (2005) identified 9 stars as members of Loden 1, and claimed that it is 2 Gyr old and 360 pc away. However, Loden 1 still remains an unconfirmed open cluster. We are conducting an on-going radial velocity survey with the SALT Robert Stobie Spectrograph to determine if Loden 1 is a real, old and nearby star cluster. If it is, then Loden 1 might provide important new targets for understanding problems such as the evolution of rotation, magnetic activity, and Lithium abundance, complementing the nearby intermediate-age clusters NGC 752 and Ruprecht 147.

442.07 – Rotational Velocities Of PMS Stars In NGC2362

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We have obtained rotation periods for ~100 stars in the young cluster NGC 2362 (t ~ 5 Myr, d ~ 1.5 kpc) and find periods ranging from P < 1 day to P ~ 14 days. Using data publically available in the ESO data archive, we have determined the v sin(i) values for a subset of our rotators for which we have rotation periods. Combining these rotation periods with the determined v sin(i), we can determine the stellar radii to a factor of sin(i). We present the results of our analysis and compare stellar radii at ~5 Myr to those of stars in younger clusters such as NGC 2264, IC 348, and the Orion Nebula Cluster.

442.08 – Rotation and activity at 3 Gyr with Ruprecht 147

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Stellar rotation slows and magnetic activity wanes over time, making these properties useful diagnostics to determine the ages of stars. While gyrochronology and Skumanich-type activity relations have been empirically calibrated for younger stars using nearby open clusters, few benchmark clusters older than 1 Gyr exist that are close enough to have activity levels measured for their main sequence stars. Pace (2013) claims that magnetic activity can no longer be used as an age indicator after ~1 Gyr (from NGC 752), but no open cluster has been available to substantiate this claim until now. We have recently

demonstrated that Ruprecht 147 is the oldest nearby open cluster, with an age of 3 Gyr and a distance of ~300 pc, which bridges the age gap between NGC 752 at 1 Gyr and M67 and the Sun at 4 Gyr (Curtis et al. 2013). We have measured projected rotational velocities (vsini) and magnetic activity indices (Calcium H&K) for >50 FGK dwarfs with high signal-to-noise spectra taken with the MMT Hectochelle, Magellan MIKE, Keck HIRES, and Tillinghast 1.5-m FAST spectrographs. We will discuss how our rotation and activity measurements for this 3 Gyr open cluster shed light on the rotation- and activity- age relations for old and late-type stars. We will also present new cluster members from our ongoing M dwarf survey with SALT RSS, discuss stellar multiplicity in light of our recently acquired Robo-AO imaging, and review our efforts to locate and characterize the white dwarf population.

442.09 – Using MASSCLEAN to Describe Stellar Clusters Found in the Vista Variables in the Via Lactea (VVV) Survey

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The important parameters of age, mass and distance of resolved or partially resolved stellar clusters are most accurately determined by using color-magnitude diagrams (CMD). However, when the main sequence turnoff is not available or clearly identifiable, large errors in all parameters result when using simple isochrone fitting, particularly when observations are limited to near-infrared bands. We used the MASSCLEAN package to perform 5 million Monte Carlo simulations of stochastically sampled stellar clusters in order to generate CMD templates for a variety of cluster masses and ages and which mimic the observational photometric errors. This results in the creation of tens of thousands of n-dimensional stellar density maps (templates) in numerous color planes as a function of age and mass. We use these MASSCLEAN CMD templates to refine and sharpen traditional isochrone fitting to analyze the newly discovered stellar clusters/cluster candidates from the Vista Variables in the Via Lactea (VVV) Survey. Our MASSCLEAN templates are also being used to design and optimize search algorithms for stellar clusters in broad-band surveys.

442.10 – A Kinematic Survey in the Perseus Molecular Cloud: Results from the APOGEE Infrared Survey of Young Nebulous Clusters (IN-SYNC)

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Contributing teams: APOGEE IN-SYNC Team

Demographic studies of stellar clusters indicate that relatively few persist as bound structures for 100 Myrs or longer. If cluster dispersal is a 'violent' process, it could strongly influence the formation and early evolution of stellar binaries and planetary systems. Unfortunately, measuring the dynamical state of 'typical' (i.e., ~300-1000 member) young star clusters has been difficult, particularly for clusters still embedded within their parental molecular cloud. The near-infrared spectrograph for the Apache Point Observatory Galactic Evolution Experiment (APOGEE), which can measure precise radial velocities for 230 cluster stars simultaneously, is uniquely suited to diagnosing the dynamics of Galactic star formation regions. We give an overview of the INfrared Survey of Young Nebulous Clusters (IN-SYNC), an APOGEE ancillary science program that is carrying out a comparative study of young clusters in the Perseus molecular cloud: NGC 1333, a heavily embedded cluster, and IC 348, which has begun to disperse its surrounding molecular gas. These observations appear to rule out a significantly super-virial velocity dispersion in IC 348, contrary to predictions of models where a cluster's dynamics is strongly influenced by the dispersal of its primordial gas. We also summarize the properties of two newly identified spectroscopic binaries; binary systems such as these play a key role in the dynamical evolution of young clusters, and introduce velocity offsets that must be accounted for in measuring cluster velocity dispersions.

442.11 – The Gaia-ESO Survey: a public spectroscopic survey of the Milky Way

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Contributing teams: the GES Consortium

The Gaia-ESO Survey (GES) is a public spectroscopic survey that will sample all major stellar components of the Milky Way galaxy and provide detailed distributions of kinematics and elemental abundances for over 100,000 stars. GES is motivated by a multitude of science goals, the overriding one being an understanding of the formation and evolution of the Galaxy and its open star clusters. Carried out on the ESO VLT with the FLAMES spectrograph, GES will provide high resolution spectra of well-defined samples that survey the Galactic bulge, thin and thick disks, and halo populations, and on the order of 100 open clusters of a range of ages, metallicities, masses and locations in the Galaxy. The data are reduced and analyzed for stellar properties and elemental abundances in a uniform way, providing a homogeneous data set that will allow the investigation of kinematic and abundance structure in the Galaxy with high precision. We summarize the status of the project, which began collecting data at the end of 2011, and present a sample of initial science results, focusing on data from the open cluster population. These results illustrate the potential of the survey to characterize cluster kinematic and abundance properties, distinguish clusters from the Galactic field through chemical tagging, and explore the Galactic abundance gradient.

442.12 – The Open Cluster Chemical Abundances and Mapping (OCCAM) Survey

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We present the current status of the Open Cluster Chemical Abundances and Mapping (OCCAM) Survey based on data from the Sloan Digital Sky Survey III/ Apache Point Observatory Galactic Evolution Experiment (SDSS-III/APOGEE). We present results of the Galactic abundance gradient using the largest uniform sample of open clusters from the APOGEE survey.

442.13 – Radial Velocities, Metallicities, and Improved Fundamental Parameters of Outer Disk Open Clusters

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Open stellar clusters have proven to be powerful tools for understanding the structure and stellar evolution of our Galaxy. Using photometry from 2MASS and the new *Spitzer*-IRAC GLIMPSE-360 surveys, Zasowski et al. (2013) identified and characterized more than a dozen new or poorly studied, heavily reddened open clusters in the outer Galactic disk. Here, we present follow-up spectroscopy for 11 of the clusters. Low resolution optical spectra were obtained with the DIS spectrograph on the Apache Point Observatory 3.5-meter telescope (R?1200) for candidate members of seven clusters (GLM-CYGX 16, GLM-G360 18, GLM-G360 105, SAI 24, Berkeley 14, Berkeley 14a, and Czernik 20), and with the B&C spectrograph on the Las Campanas Observatory duPont telescope (R?5400) for three clusters (GLM-G360 50, GLM-G360 75, and GLM-G360 79). High resolution (R?22,500) infrared (H-band) spectra were also obtained for one cluster (GLM-G360 90) as part of an ancillary program for the SDSS-III/APOGEE survey. We use the mean chemical abundances and radial velocities (RVs) to identify likely cluster members and then revisit our previous isochrone fits. With reddening constrained by the Rayleigh-Jeans Color Excess method and mean metallicities by spectroscopy, the cluster distances and ages are estimated from improved isochrone fits to the stellar overdensity, weighted by confirmed RV and/or abundance members.

442.14 – Analysis of Spectral-type A/B Stars in Five Open Clusters

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We have obtained low resolution (R = 1000) spectroscopy of N=68, spectral-type A/B stars in five nearby open star clusters using the McDonald Observatory, 2.1m telescope. The sample of blue stars in various clusters were selected to test our new technique for determining interstellar reddening and distances in areas where interstellar reddening is high. We use a Bayesian approach to find the posterior distribution for Teff, Logg and [Fe/H] from a combination of reddened, photometric

colors and spectroscopic line strengths. We will present calibration results for this technique using open cluster star data with known reddening and distances. Preliminary results suggest our technique can produce both reddening and distance determinations to within 10% of cluster values. Our technique opens the possibility of determining distances for blue stars at low Galactic latitudes where extinction can be large and differential. We will also compare our stellar parameter determinations to previously reported MK spectral classifications and discuss the probability that some of our stars are not members of their reported clusters.

442.15 – Spectroscopic Binary Orbits in the Young Open Cluster M35

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The young (150 Myr) open cluster M35 has been one of the core clusters of the WIYN Open Cluster Study (WOCS) since 1997. Over these 15 years we have obtained nearly 8000 radial-velocity (RV) measurements of stars in the M35 field. Our target sample consists of 1355 photometrically selected stars in the field of M35 within the main sequence and binary sequence of the cluster with $13 < V < 16.5$ and $(B-V) > 0.6$. It also includes a few X-ray sources revealed in XMM-Newton observations. Using our RV measurements we have been able to adequately separate likely cluster members from field stars. We have RV membership probabilities for over 1200 stars in our sample, over 400 of which are probable cluster members. Our survey has also revealed 240 velocity-variable stars. Here we present more than 50 orbital solutions of variable cluster members. This sample defines the hard binary population of M35 that dynamically powers the cluster, and enables us to investigate important properties such as the period-eccentricity distribution, binary frequency, and the secondary mass distribution of M35. Understanding these properties in a young cluster is key to defining the initial conditions used in models of cluster dynamical evolution. Support for this program is provided by the National Science Foundation through grant AST-0908082.

442.16 – NGC6791: A case study of using CN and CH band strengths to detect chemical inhomogeneities in open clusters.

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We present an analysis of the CN and CH molecular band strengths for cluster members of the open cluster NGC 6791 using low resolution ($R \sim 2000$) SEGUE spectra. The spectra were taken as part of the validation process for the SEGUE Stellar Parameter Pipeline (SSPP) and released in the eighth SDSS data release. If there are star-to-star abundance variations present at a given evolutionary state in a stellar population, they may be observed through variations in the molecular band strengths at that stage. Characterizing these variations in globular clusters has shown that the band strengths form a bimodal distribution, indicative of cluster members with different chemical abundances and possibly multiple generations of stars. In this work, we use this technique on an open cluster (NGC 6791) to address the possibility of abundance variations present in the cluster. Performing this analysis on other open clusters has resulted in unimodal distributions of CN and CH band strengths, as expected from their typical physical characteristics. NGC 6791, however, provides an interesting case study for this analysis due to its high mass $\sim 5 \times 10^4$ solar masses, old age ~ 8 Gyr, and high metallicity [Fe/H] $\sim +0.4$ dex, making it a less than typical open cluster. For this reason, NGC 6791 has been the subject of other studies (see Twarog, et al. 2011; Geisler, et al. 2012; Carrera, 2012) focused on detecting abundance variations in the cluster using broadband photometry, high resolution spectra, and molecular band strengths. These studies have found some evidence for abundance variations among the cluster members, but there is still debate as to whether these findings are conclusive. In this study, we do not find evidence to support abundance variations between cluster members of NGC 6791.

442.17 – New Deep Photometry and Stellar Luminosity Functions for Ko 1 and Ko 2

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We present new, deep, VI photometry of the clusters Ko 1 and Ko 2 taken using the Discovery Channel telescope. The photometry extends two magnitudes deeper than any existing photometry. Isochrone fits and an examination of the stellar luminosity function and mass function of the main sequence are completed.

442.18 – A Swift/UVOT Survey of Galactic Open and Globular Clusters

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We present the first results of a survey of open and globular clusters using the Ultraviolet Optical Telescope (UVOT) aboard the Swift Gamma-Ray Burst Mission. Photometry of 50 open and globular clusters from UVOT reveals the expected sequences of bright main sequence stars, blue horizontal branch stars and extreme horizontal branch stars. It also reveals unusual hot UV-bright stars such as AGB Manque stars and Post-Asymptotic Giant Branch Stars. Comparison to theoretical isochrones and HB evolution models indicate good agreement with the data. UVOT's ability to detect and characterize hot UV-bright stars promises better constraint on evolutionary models and an improvement in our understanding of more distant unresolved stellar populations.

442.19 – A Swift/UVOT NUV Study of RR Lyrae Stars in the Globular Cluster M3

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Contributing teams: Swift, UVOT

We present the first results of a program to monitor RR Lyrae stars in globular clusters with the Swift Ultraviolet Optical Telescope. Although variable stars have their strongest pulsations in the UV, no comprehensive catalog of NUV light curves has ever been produced for RR Lyrae stars. We present uvm2 light curves for 124 variable star candidates in the globular cluster M3. We show that the RR Lyrae stars have strong pulsations in the NUV, with amplitudes up to three magnitudes. We show that the RR Lyrae follow period-amplitude relations in the NUV similar to those they follow in the optical. Our data hint at the existence of a period-metallicity-luminosity relationship in the UV that would make RR Lyrae even more useful standard candles.

442.20 – Physical Parameters of the Bulge Globular Cluster Terzan 5 from Long-Term Millisecond Pulsar Timing

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We present new measurements of key physical properties of the globular cluster Terzan 5 by using long-term measurements of the ensemble of 34 millisecond pulsars located within it. This cluster is located within the galactic bulge and suffers from heavy reddening that makes studies of normal stars difficult. Pulsars provide a completely independent way to study the intrinsic characteristics of the core that does not suffer from reddening effects. We demonstrate our method is able to produce a core radius, velocity dispersion, and density that agrees with the most recent Hubble observations. We also include a discussion on the merit of using measured stellar densities to predict the higher order spin frequency derivatives of the pulsars in our ensemble.

442.21 – Photometric Metallicities of Stars in the Retrograde Globular Cluster, NGC 3201

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NGC 3201 is in a rare, retrograde orbit around the Milky Way. Since 1998, several groups have suggested that it is the remnant of a larger, captured system because there is also evidence of a spread in chemical composition in the RGB stars. Some spectral samples infer a spread in [Fe/H] of up to 0.4 dex (around an average of [Fe/H]=-1.5 dex), and others claim it is less than 0.12 dex. However, even the studies which do not find a distinguishable spread in [Fe/H] show other chemical signatures of multiple episodes of star formation. High-resolution spectral analysis is limited to upper-RGB stars because of the S/N required. To explore the chemical composition of unmixed stars, we must observe fainter, less evolved objects, which can only be reached with low-resolution spectra and imaging (as yet). Photometric studies are complicated by a steep extinction gradient towards the cluster, which may be complicated by a non-standard extinction law. We explore several different methods of removing the uneven interstellar extinction, to minimize the effects on Stromgren photometry of the stellar population. Our derived extinction maps show that using the E(B-V)=0.21+/-0.03 mag average value is not valid, as the range in extinction is position-dependent and 0.22-0.29; it would introduce a spread in photometrically estimated [Fe/H]-values of +0.1 dex and -0.3 dex independent of any other factors. Minimizing the uncertainty due to the foreground extinction will allow us to reduce the systematic effects to +0.05 and -0.15 dex, enabling us to show that the spread in [Fe/H] is real, from the m1- or reddening-free [m]-index. We also test samples of RGB stars claimed to be single metallicity to look for CN-effects.

442.22 – Chemical Abundance Patterns of Galactic Bulge Globular Clusters

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The Galactic bulge globular clusters are interesting but poorly understood stellar systems. The number of bulge globular cluster stars for which detailed chemical abundance information is available is considerably smaller than for halo cluster stars. However, there is growing evidence that many of the bulge globular clusters exhibit interesting characteristics, such as: double horizontal branches, populations separated by more than a factor of two in metallicity, high metallicity clusters with very blue horizontal branches, and large star-to-star variations of heavy element abundances. In order to investigate some of these problems, we have obtained high resolution spectra of several stars in multiple bulge globular clusters in order to measure detailed chemical abundance patterns. We make use of both new observations with the WIYN-Hydra and Magellan-MIKE spectrographs, and also archival data from VLT-FLAMES. We measure the abundances of several light odd-Z, alpha, Fe-peak, and neutron-capture elements, and compare the bulge globular cluster patterns with those in halo clusters and the bulge field. C.I.J. acknowledges support through the Clay Fellowship administered by the Smithsonian Astrophysical Observatory.

442.23 – Comparing Light Element Abundances for 47 Tucanae (NGC 104) and M71 (NGC 6838)

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Improving our understanding of the origin of the multiple populations in globular clusters requires both additional theoretical and observational work. In particular, light element abundances for large sample of stars are needed to test theoretical models of cluster formation and to characterize the nature of the polluters responsible for the chemical patterns seen in globular clusters. We present detailed chemical abundances for M71 and 47 Tucanae using moderate-resolution WIYN-Hydra, CTIO-Hydra, and VLT/FLAMES spectra of red giant stars. O, Na, and Al are used to study the different chemical populations. The analysis of the more metal-rich cluster of our sample has been completed and we found that the O-depleted population in 47 Tucanae is more centrally concentrated than the primordial population consistent with theoretical predictions. We compare our results obtained for 47 Tucanae with M71 which has a similar metallicity.

442.24 – New Stellar Debris Streams in the Sloan Digital Sky Survey

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We describe several new tidal debris streams found through matched-filtering techniques applied to the Sloan Digital Sky Survey. The streams vary in length from 30 to 50 degrees and have estimated distances ranging from 10 to 50 kpc. Efforts are underway to confirm the familial and co-moving nature of the stars in these streams, and to identify their progenitors.

442.25 – Rapid dynamical processes in the cores of young star clusters in the Large Magellanic Cloud

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Using high-resolution Hubble Space Telescope observations, we investigate the radial distributions of the F-type main-sequence binary fractions in the massive young Large Magellanic Cloud star clusters NGC 1805 and NGC 1818. The binary fractions in these two clusters are characterized by opposite trends in their radial profiles. Time-scale arguments imply that early dynamical mass segregation should be very efficient and likely dominates the dynamical processes in the core of NGC 1805, while in NGC 1818 the behaviour in the core is probably dominated by disruption of soft binary systems. We speculate that this may be caused by the higher velocity dispersion in the NGC 1818 core, which creates an environment in which the efficiency of binary disruption is high compared with that in the NGC 1805 core.

442.26 – Consequences of Dynamical Disruption and Mass Segregation for the Binary Frequencies of Star Clusters

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The massive (13,000 - 26,000 solar masses), young (15 - 30 Myr) Large Magellanic Cloud star cluster NGC 1818 reveals an unexpected increasing binary frequency with radius for F-type stars (1.3 - 2.2 solar masses). This is in contrast to many older star clusters that show a decreasing binary frequency with radius. We study this phenomenon with sophisticated N-body modeling, and find that many different initial configurations evolve to reproduce the cluster's observed properties, although with a modest preference for substructured initial conditions. Our models produce the observed radial trend in binary frequency through disruption of soft binaries on approximately a crossing time, preferentially in the cluster core. At later times mass segregation processes dominate binary disruption and transform the radial distribution of the binary frequency first into a bimodal distribution, and then into a radial distribution that peaks only in the core. Thus, both a radial binary frequency distribution that falls towards the core (as observed for NGC 1818) and one that rises towards the core (as for older star clusters) can arise naturally from the same evolutionary sequence owing to binary disruption and mass segregation in rich star clusters.

442.27 – The Hubble Tarantula Treasury Project

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The Tarantula Nebula (a.k.a. 30 Doradus) in the Large Magellanic Cloud is one of the most famous objects in astronomy, with first astronomical references being more than 150 years old. Today the Tarantula Nebula and its ionizing cluster R136 are considered one of the few known starburst regions in the Local Group and an ideal test bed to investigate the temporal and spatial evolution of a prototypical starburst on a sub-cluster scale. The Hubble Tarantula Treasury Project (HTTP) is a panchromatic imaging survey of the stellar populations and ionized gas in the Tarantula Nebula that reaches into the sub-solar mass regime (<0.5 M™). HTTP utilizes the capability of the Hubble Space Telescope to operate the Advanced Camera for Surveys and the Wide Field Camera 3 in parallel to study this remarkable region in the near-ultraviolet, optical, and near-infrared spectral regions, including narrow-band Hα images. The program was awarded 60 orbits of HST time and is built on the existing 30 orbits monochromatic proper motion program GO-12499 (PI Lennon). The combination of all these bands provides a unique view of the region: the resulting maps of the Tarantula's stellar content provide the basis for investigations of star formation in an environment resembling the extreme conditions found in starburst galaxies and in the early universe. At the same time access to detailed properties of individual stars allows us to begin to reconstruct the temporal and spatial evolution of the Tarantula Nebula over space and time on a sub-parsec scale. We will deliver high-level data products (i.e. star and cluster catalogs, co-registered stacked images). HTTP will become the definitive catalog of the field, and have lasting value for future. HTTP also has an educational and public outreach component aimed to stimulate interest in STEM disciplines among people with visual impairments. "Reach for the Stars: Touch, Look, Listen, Learn" is a free eBook that explains how stars form and evolve using images from HTTP. The eBook utilizes emerging technology that works in conjunction with the built-in accessibility features in the Apple iPad to allow totally blind users to interactively explore complex astronomical images.

442.28 – Spectral Types and Wind Velocities for Massive Stars in R136

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We analyze spatially resolved, long-slit ultraviolet (UV) and optical stellar spectra of the compact starburst cluster R136 at

the core of 30 Doradus. R136 is young and massive, making it an ideal place to study the upper end of the initial mass function. These spectra, taken with the Space Telescope Imaging Spectrograph on the Hubble Space Telescope, cover over 100 stars in the inner 4 arcseconds (1 parsec) of R136, a region which cannot be resolved with ground-based spectroscopy. In this poster we present both the UV and optical of over 20 of the brightest stars in R136, extracted with MULTISPEC, a tool written specifically for multiple objects in crowded fields. For each star we present an optical spectral type and a terminal wind velocity derived from the UV data

442.29 – The Low-Mass Luminosity Function in Globular Clusters

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We present a novel technique for self-consistently constraining the full luminosity function of globular clusters by measuring the cumulative fraction of light from resolved stars as a function of the total integrated cluster light. Using HST WFPC2 observations of a sample of six metal-poor clusters in the Large Magellanic Clouds (NGC 1754, 1835, 1898, 1916, 2006, and 2019), we have resolved stars down to the main sequence turn-off. Color-magnitude diagrams for each cluster show well-developed horizontal branches, and the luminosity functions display the expected power law of 0.3 along the red giant branch. Using the ratio of resolved to unresolved light, we then smoothly extrapolate the luminosity function below the (currently unresolved) main sequence turn-off. This technique allows for new and independent constraints on the initial mass function for globular clusters.

442.30 – First Results from the Swift/UVOT Near-Ultraviolet Survey of the SMC

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The Swift Ultraviolet/Optical Telescope (UVOT) has recently completed the first wide-field multi-color NUV survey of the Small Magellanic Cloud. The resulting images, the product of nearly two complete days of imaging, covers nearly four square degrees and includes over 250,000 NUV sources. We present the first analysis of this outstanding data set, looking at the recent star formation history of the SMC, the distribution of young stellar populations over the face of the SMC, the location of rare stellar types such as Post-Asymptotic Giant Branch stars, and the SMC dust extinction law.

442.31 – Detecting Reddening by Dust for Star Clusters in the Andromeda Galaxy

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Contributing teams: PHAT collaboration

We have developed a technique to detect reddening by interstellar dust of star clusters in the Andromeda Galaxy, using Hubble Space Telescope ACS/WFC imaging in B and I and spectroscopic data from Keck II DEIMOS spectrograph. These data are from the Panchromatic Hubble Andromeda Treasury (PHAT) and Spectroscopic and Panchromatic Landscape of Andromeda's Stellar Halo (SPLASH) surveys. We compared the observed color indices from the PHAT data to the intrinsic color indices quantitatively inferred from a chi-squared goodness of fit comparison between the SPLASH data and a library of template spectra, to detect reddening. The spectral comparison utilizes the strength of the titanium oxide bands. This technique will be applied to an additional 150 star clusters, in Andromeda, to determine the amount of reddening they have experienced. It will also be used as part of the process of correcting for the reddening, developing a reddening law, and learning more about the physical properties of the dust. This research was carried out under the auspices of UCSC's Science Internship Program. We thank the National Aeronautics and Space Administration and the National Science Foundation for funding support.

442.32 – The Andromeda Project: Final Results of Citizen Science Cluster Identification

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Contributing teams: PHAT Team, Andromeda Project Team

The Panchromatic Hubble Andromeda Treasury (PHAT) survey has completed data collection, having taken over 30 billion pixels of imaging data of the Andromeda galaxy over four years using the Hubble Space Telescope. These data contain the largest sample of star clusters observable in any galaxy, including our own Milky Way. The Andromeda Project is a citizen science project that recruited over 10,000 volunteers to identify thousands of star clusters in the PHAT imaging. We present results culminating from two rounds of cluster searching and the properties of the resulting sample. We discuss catalog completeness results derived from synthetic cluster data. This cluster sample represents a significant advance in our ability to study star and cluster formation on galaxy wide scales. We are using the resulting cluster sample to provide the best available constraints on the high-mass initial mass function and the fraction of star formation that results in bound star clusters.

442.33 – Early Results from Star Date: M83 - A Citizen Science Project to Age Date Star Clusters in the Southern Pinwheel Galaxy

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The M83 Citizen Science Project is a collaborative effort currently in development between the Space Telescope Science Institute (STScI) and Zooniverse under the guidance of Dr. Brad Whitmore as part of Cy 19 proposal 12513 (PI – Dr. William Blair). This unique citizen science project will allow users to analyze individual star clusters within The Southern Pinwheel Galaxy, M83. The project will show users color-composite images taken with Wide Field Camera 3 (WFC3) aboard the Hubble Space Telescope (HST) and ask them to estimate the age of the star cluster. Through a multistage process, the project will educate and familiarize the user with the appearance of each age category based on the presence and shape of H-alpha emission, degree of resolution of the individual stars, and color of the cluster. (Whitmore et al. 2011). Additionally, the project will involve the actual measurement of the star cluster and H-alpha cloud radii to be used for further assessment and reinforcement of age. The data from this project and the statistics it yields will quantify these ages which can then be used to inform the debate between universal and environmental models of star cluster formation and destruction in galaxies. The tentative launch date is December 2013, therefore early results should be available at the time of the conference.

442.34 – Cluster Ages in the Tidal Tail of the Merger NGC 3256

Alexander Mulia[1], Rupali Chandar[1]
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It is well known that major galaxy mergers are often accompanied by bursts of star formation in the main bodies of the galaxies. However, it is not yet clear whether star formation always occurs within the tidal tails as they are created by material expelled from the merging system. To determine which mergers have star formation in their tails and why, we are investigating the star cluster populations in the tidal tails of four nearby merging systems. In this contribution, we present results for NGC 3256, based on multi-band optical imaging taken with the Advanced Camera for Surveys/Wide Field Camera on the Hubble Space Telescope. Cluster ages are estimated by comparing the observed colors with predictions from simple stellar population models. We find that a significant fraction of clusters are younger than the dynamically predicted age of the tail, but that no very recent (<10 Myr) cluster formation has occurred. There are also a number of older clusters, which have a more even spatial distribution across the tail than the younger clusters. These findings suggest that the younger clusters probably formed in the tail, while the older clusters may have been thrown out from the progenitor galaxies at the same time as the tidal material.

442.35 – The Luminosity Function of Star Clusters in 20 Star-Forming Galaxies Based on Hubble Legacy Archive Photometry

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Luminosity functions have been determined for star cluster populations in 20 nearby (4 - 30 Mpc), star-forming galaxies based on ACS source lists generated by the Hubble Legacy Archive (http://hla.stsci.edu). These cluster catalogs provide one of the largest sets of uniform, automatically-generated cluster candidates available in the literature at present. Comparisons are made with other recently generated cluster catalogs demonstrating that the HLA-generated catalogs are of similar quality, but in general do not go as deep. A typical cluster luminosity function can be approximated by a power-law, dN/dL ? Lα, with an average value for α of -2.37 and rms scatter = 0.18. A comparison of fitting results based on methods which use binned and unbinned data shows good agreement, although there may be a systematic tendency for the unbinned (maximum-likelihood) method to give slightly more negative values of α for galaxies with steeper luminosity functions. Our uniform database results in a small scatter (0.5 magnitude) in the correlation between the magnitude of the brightest cluster (Mbrightest) and Log of the number of clusters brighter than MI = -9 (Log N). We also examine the magnitude of the

brightest cluster vs. Log SFR for a sample including LIRGS and ULIRGS.

442.36 – The Size Scales of Stellar Groupings in NGC 628 and NGC 2841

Molly Williams[2], Catherine C. Kaleida[1]
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We present size histograms of manually selected stellar associations in the Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3) images of NGC 2841 and NGC 628. Furthermore, we present color-magnitude diagrams (CMDs) and color-color diagrams (CCDs) for associations in these two galaxies as a way to better understand the completeness of the manual and automated selection processes used. Galactic (foreground) stars were identified and indicated on the CMDs and CCDs. It was determined by a variety of measures that individual stars in the galaxy are not resolvable for NGC 2841; however, more tests are needed in order to say the same for NGC 628. Size histograms of the stellar associations detected in each galaxy were made in order to compare the nature of stellar clustering in flocculent versus non-flocculent spiral galaxies.

442.37 – Age and Mass Distributions of Resolved Stellar Populations in NGC 4214 based on HST/WFC3 ERS Observations

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Contributing teams: WFC3 SOC

The dwarf starburst galaxy NGC 4214 (D = 3.0 Mpc) is an ideal laboratory to study formation and evolution histories of individual stars since it is filled with multiple stellar populations ranging from stars in hot young star-forming regions (< 10 Myr) to those in old clusters (> 100 Myr). Here we present a detailed multi-wavelength photometric study of resolved stellar populations in NGC 4214 based on HST WFC3 observations using five filters: F225W, F336W, F438W, F547M, and F814W. We use extinction-corrected color-magnitude diagrams and color-color diagrams to determine the ages and masses of individual stars. We also present spatial distribution maps of the ages and masses of individual stars. These maps show that the young massive stars (> 8 M_sun) are more clustered and associated with the strong H-alpha emission regions and the OB associations, whereas the old low-mass stars are more spread out across the galaxy. This project is based on Early Release Science observations made by the WFC3 Scientific Oversight Committee. We are grateful to the Director of the Space Telescope Science Institute for awarding Director's Discretionary time for this program. Support for program 11360 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555.

442.38 – Testing the Universality of the IMF with Unresolved Stellar Clusters

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Contributing teams: WFC3 ERS

The production rate of ionizing photons in young < 8 Myr, unresolved stellar clusters in the nearby galaxies NGC 4214 and M83 is probed using multi-wavelength Hubble Space Telescope WFC3 data. We normalize the ionizing photon rate by the cluster mass to investigate the upper end of the stellar initial mass function (IMF). We have found that within the uncertainties the upper end of the stellar IMF appears to be universal in both galaxies, and that deviations from a universal IMF can be attributed to stochastic sampling of stars in clusters with masses < 10^3 M_sun. Furthermore, we have found that there does not seem to be a dependence of the maximum stellar mass on the cluster mass. We have also found that for massive clusters, feedback may cause an underrepresentation in Ha luminosities, which needs to be taken into account when conducting this type of analysis.

442.39 – The Spatial Distribution of Virgo's Globular Clusters

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Contributing teams: NGVS Team

We present the results for a search for globular clusters (GCs) throughout the Virgo Cluster, using deep g'i' photometry from

the Next Generation Virgo Cluster Survey (NGVS), a large imaging program using the CFHT+MegaCam from which to study the entire cluster out to the virial radius. We estimate a total population of ~65000 GCs within our Virgo survey region (covering over 104 square degrees), where the red GCs are largely located within or near the many luminous early type galaxies, while the blue GCs have spatial profiles that extend into intracluster space. In particular, the core region (containing M87) shows a highly irregular spatial distribution that includes regions of likely intracluster globular clusters (IGCs).

442.40 – The Projected Spatial Distributions of Giant Galaxy Globular Cluster Systems: Analysis of Four Giant Early-Type Galaxies

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The properties of globular cluster (GC) populations of giant galaxies -- including their spatial distributions about their host galaxies -- provide important observational constraints to theoretical scenarios of galaxy formation and evolution. Although the radial distribution of galaxy GC systems have been well-studied, the properties of the azimuthal distribution (projected 2D shape) of GC systems have received relatively little attention. We present the results of the azimuthal distribution analysis of the GC systems of a sample of four giant E/S0 galaxies from our ongoing wide-field optical imaging survey of giant galaxy GC populations. We obtained deep, three filter (BVR) imaging with the KPNO 4m+MOSAIC configuration to both characterize the galaxies' GC population and obtain surface photometry of the host galaxies. The ellipticity and position angle of a galaxy's GC system were measured using an iterative method of moments algorithm with uncertainties determined via numerical simulations. For the giant ellipticals NGC 4406 and NGC 5813, we find that the GC systems show an elliptical 2D spatial distribution consistent with the host galaxy light. For the giant elliptical NGC 4472, our analysis suggests an elliptical distribution of GCs consistent with the host galaxy light, but the relatively low numbers of detected GC candidates in the B band precludes a strong conclusion. For the S0 galaxy NGC 4594, we do not detect an elliptical distribution of GCs that is significantly different from circular, in contrast to the host galaxy light which becomes flattened in the inner regions. We examine the individual metal-poor and metal-rich subpopulations in NGC 4406 and NGC 5813 and find that, for each galaxy, both subpopulations show elliptical azimuthal distributions consistent with the host galaxy light. The similar azimuthal distributions of the host galaxy light and GC systems in the two ellipticals is an important constraint to galaxy/GC formation scenarios and may reflect the large-scale dynamical evolution of the host galaxy (i.e., violent relaxation and velocity anisotropy). The work on this project has been supported by NSF AST-0847109 and AST-1151462.

442.41 – Highlights from a Wide-field Photometric Survey of the Globular Cluster Populations of Giant Galaxies

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I will present recent results from a wide-field imaging survey of the globular cluster populations of a sample of giant galaxies, along with selected results from several spin-off projects made possible by the survey data. We use mosaic CCD cameras on the WIYN 3.5-m and Kitt Peak 4-m telescopes to image the globular cluster populations out to their full radial extent and select point-source globular cluster candidates in three filters (BVR or gri) to minimize contamination and enable analysis of the globular cluster color distributions. The ~35 galaxies observed to date for the survey have a range of morphological types (spiral, S0, elliptical), luminosities (M_V ~ -19 to -23), and environments (field, group, cluster) and each galaxy hosts anywhere from ~50 to several thousand globular clusters. I will summarize our findings regarding the total numbers,spatial distributions, and color (metallicity) distributions of the globular cluster populations of the target galaxies. I will also highlight results from several applications of the survey data, including an investigation of the possible link between supermassive black holes and globular cluster populations and follow-up spectroscopic studies that have yielded globular cluster metallicities, kinematics, and galaxy mass profiles for a subset of the galaxies so far. This work is supported by NSF FAculty Early Career Development (CAREER) award AST-0847109.

442.42 – Investigating the Evolutionary Role and Structure of Binaries in Milky Way Globular Clusters through Correlational Studies of Binary Fraction

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Poor detection techniques such as radial velocity surveys have limited our understanding of binaries in globular clusters. Theory regarding these systems has instead relied on N-body and Monte Carlo simulations, which depict their significant potential role on a cluster's stellar interactions, core collapse, stellar evaporation, and internal energy. Using observational data recently gathered through the reliable CMD detection method, our project searched for correlations between cluster properties specifically involved in binary simulations and the detected binary fraction. Both monovariate and multivariate approaches enabled us to compare the resulting relationships with those outlined under current models. Our analysis of concentration, core radius, and the central brightness profile provides strong empirical support that binaries delay the onset

of core collapse. Furthermore, study of mass function slope and metallicity suggests that existing binaries accelerate stellar evaporation and are not primordial in nature. However, the high binary fraction found in clusters with low velocity dispersion and high absolute magnitudes contradicts theoretical expectations, and raises the possibility that a larger portion of these systems may be soft, rather than hard, binaries. Because modeling of globular clusters relies heavily on the assumption cluster binaries are primarily hard, further data detailing the structure of binary systems is needed to validate our theory and better our understanding of cluster evolution.

442.43 – A Variable [OIII] Emission Source in Black Hole Host Globular Cluster RZ2109

Matthew M. Steele[1], Steve E. Zepf[2], Thomas J. Maccarone[3], Arunav Kundu[4], Katherine L. Rhode[5], John J. Salzer[5]

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We present a optical spectra from an ongoing monitoring program of black hole hosting globular RZ2109 located in the Virgo elliptical NGC4472. The collected low (R~400) to moderate (R~2000) resolution spectra span a 5 year period from 2007-2013. The cluster's spectra display extremely broad [O III]4959,5007 lines with widths of ~3000 km/s and a noteworthy lack of any other strong emission feature. Over the period of monitoring the [O III] emission line feature displays behaviors ranging from multi-year spans with only minor variability to active periods of 25 percent or more year-over-year changes in line luminosity. In this work we examine the variability of the [O III] emission line source luminosity and line profile, and consider the implications of these observations on models of the RZ209 accreting black hole and it's interaction with the cluster environment.

442.44 – Extragalactic Globular Cluster Systems Properties as a Function of the Environment

Peter Pessev[1]

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During the passed quarter of a century the field of extragalactic globular cluster systems research showed a rapid progress, benefiting on the new detectors and more powerful observing facilities. At the beginning of the current year Harris, Harris and Alessi compiled all the information available to date into a comprehensive catalog of extragalactic globular cluster systems properties. This catalog contains data about 422 extragalactic systems, covering the entire Hubble sequence and spanning a large range of galaxy environments. In the current presentation I am evaluating the role of the galaxy environment on the properties of the globular cluster system. A sample of isolated galaxies is defined by an extensive literature search. The properties of their globular cluster systems are compared to the rest of the sample. Furthermore for galaxy types populating a broad range of different environments the globular cluster systems evolution is presented. Results are compared to earlier publications based on limited samples of galaxies.

442.45 – Modeling Gas Evacuation Mechanisms in Globular Clusters

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1. University of California, Santa Cruz, Santa Cruz, CA, United States.

Modeling globular clusters 47 Tucanae, M15, NGC 6440, and NGC 6752, we examine the effects of mass supply from a population of evolved stars with the presence of energy injection from an abundant main sequence stellar population and then compare our results to observational constraints. We find that the energy injection from the main sequence stellar members is capable of sufficiently clearing the evolved stellar ejecta to produce intracluster gas densities consistent with observational constraints. Since main sequence stars are found universally within globular clusters, this may be the driving force responsible for the tenuous medium within clusters. In addition, our analysis is extended to examine the efficiency of pulsar wind feedback in globular clusters. We find that the pulsar wind thermalization efficiency must be extremely low in the cluster's core in order to be in accordance with density constraints.

443 – Black Holes Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

443.01 – The NuSTAR Ultraluminous X-ray Source Program

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Contributing teams: The NuSTAR Team

The origin of the extreme luminosities displayed by ultraluminous X-ray sources (ULXs) may relate to either super-Eddington accretion or the presence of black holes more massive than standard stellar remnants, e.g. intermediate mass black holes with masses of 100's or 1000's of solar masses. As yet, this origin remains undetermined despite significant observational efforts with soft X-ray missions. The Nuclear Spectroscopic Telescope Array (NuSTAR), launched in June 2012, will probe the hard X-ray emission from ULXs, opening up a new observational window into these enigmatic sources. In combination with coordinated XMM-Newton and Suzaku observations providing simultaneous soft X-ray coverage, these high energy observations will provide unprecedented broadband X-ray spectra for a sample of highly luminous ULXs in the first two years of operation, allowing us to further probe the nature of these sources. Here, we discuss plans and predictions for the NuSTAR ULX program, and highlight some early results from this program.

443.02 – The ALMA Phasing Project: New Frontiers in Ultra-High Resolution Astronomy Enabled by a Beamformed ALMA

Lynn D. Matthews[1], W. Alef[2], James Anderson[2], D. Barkats[3], Geoffrey B. Crew[1], S. S. Doeleman[1], Vincent L. Fish[1], J. Greenberg[4], M. H. Hecht[1], R. Hiriart[4], M. Honma[5], Caterina Impellizzeri[3], M. Inoue[6], R. Lacasse[4], B. Lopez[3], M. Mora-Klein[4], N. Nagar[7], V. Pankratius[1], N. Pradel[6], H. Rottmann[2], A. Roy[2], C. Ruszczyk[1], A. Saez[3], B. Shillue[4], R. Treacy[4]
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Contributing teams: The ALMA Phasing Project Team

The Atacama Millimeter/submillimeter Array (ALMA) Phasing Project (APP) is an ongoing ALMA Development Project that will provide the means to coherently sum all of the individual ALMA antennas, allowing them to effectively function as a single aperture. This capability will allow ALMA to participate in global Very Long Baseline Interferometry (VLBI) networks operating in the millimeter and submillimeter, offering a dramatic improvement in sensitivity. This will in turn afford a wide range of new ultra-high angular resolution science applications. This poster will provide an overview of the APP design and implementation plan and highlight examples of new science enabled by a beamformed ALMA (including the study of black holes on Event Horizon scales, the detailed investigation of the launch and collimation of astrophysical jets, and astrometry of astrophysical masers with unprecedented precision). Commissioning and Science Verification of the APP is slated to begin in early 2014.

443.03 – Selection of Dual AGN Candidate Using Wise & Galaxy Zoo: A Chandra Pilot Study

Raj K. Koju[1]
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Since the vast majority of galaxies contain supermassive black holes (SMBHs) and galaxy interactions trigger nuclear gas accretion, a direct consequence of the hierarchical model of galaxy formation would be the existence of binary active galactic nuclei (AGNs). The existence, frequency, and characteristics of such binary AGNs have important astrophysical implications on the SMBH mass function, the interplay between SMBHs and the host galaxy, and the M-? relation. Despite decades of searching, and strong theoretical reasons that they should exist, observationally confirmed cases of binary AGNs are extremely rare, and most have been discovered serendipitously. Using extremely red mid-IR colors from the all-sky WISE survey and Galaxy Zoo close interaction identifications, we identified a sample of 90 strongly interacting galaxies with mid-IR signatures of powerful AGNs. Although these galaxies are optically quiescent, all galaxies in the sample for which archival Chandra observations are available, contain double X-ray nuclear sources suggestive of dual AGNs. We present these archival X-ray observations. This study suggests that the WISE survey may open up a promising pre-selection strategy for finding dual AGNs that is complementary to optical studies and will enable larger systematic investigations of dual AGN candidates.

443.04 – New Developments with the Event Horizon Telescope

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Contributing teams: Event Horizon Telescope Collaboration

The Event Horizon Telescope is an international collaboration to observe nearby supermassive black holes with millimeter-wavelength very long baseline interferometry in order to probe the region of the black hole shadow. Previous observations have placed strong constraints on the morphology of the emitting region around Sagittarius A* and the supermassive black hole in the center of M87, resulting in greater insight into the processes of accretion and outflow around black holes. Substantial advances in data quality have been made in the most recent March 2013 observations. Linear polarization has been clearly detected toward a variety of sources on angular scales of tens to hundreds of microarcseconds. Interhemispheric fringes, both North-South and East-West, were obtained, providing the best EHT baseline coverage to date. Technical progress on other stations that may participate in the 1.3 mm VLBI array, including a successful 3 mm VLBI experiment with the Large Millimeter Telescope and continued development of the ALMA beamformer, will soon increase the array sensitivity and baseline coverage, permitting imaging of black holes for the first time.

443.05 – Black holes under the microscope: Prospects for imaging with the Event Horizon Telescopes

Rusen Lu[1], Vincent L. Fish[1], Sheperd Doeleman[1, 2], John D. Monnier[3], Fabien Baron[4]
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Recent Event Horizon Telescope (EHT) observations have identified Schwarzschild-radius-scale emission around the black holes in Sgr A* and M87. We perform realistic VLBI simulations and explore well-established imaging algorithms that are optimized for data sets like those from the EHT to examine the model-independent detectability of black hole shadow features. With the expected substantial improvements in the uv coverage and sensitivity over the next few years, we show that the EHT will be able to image the jet launch region and the shadow cast by the black hole on its surrounding emission in M87 and Sgr A*, providing new insights on jet launching physics and tests of the fundamental predictions of general relativity.

443.06 – Moving Toward Polarimetry with the Event Horizon Telescope

Michael Kosowsky[1], Vincent L. Fish[3], Sheperd Doeleman[2, 3], Michael Johnson[2], Rusen Lu[3], Daniel P. Marrone[5], James M. Moran[2], Richard L. Plambeck[4], John F. Wardle[1]
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Contributing teams: EHT Collaboration

The Event Horizon Telescope (EHT) project aims to develop millimeter and submillimeter VLBI to achieve angular resolution of tens of microarcseconds, comparable to the event horizons of nearby supermassive black holes. A major challenge for polarimetry at these scales is instrumental cross-talk, which introduces spurious linear polarization that can easily overwhelm the intrinsic signal. We demonstrate a new method for correcting the instrumental response, based on Markov Chain Monte Carlo simulations and other non-linear fitting methods. We will present preliminary polarimetric results on several EHT targets. Future EHT observations will provide a new window into the rich magnetic structures of their innermost cores.

443.07 – Hyperaccretion during tidal disruption events: weakly bound debris envelopes and jets

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After the destruction of the star during a tidal disruption event (TDE), the cataclysmic encounter between a star and the supermassive black hole (SMBH) of a galaxy, approximately half of the original stellar debris falls back onto the hole at a rate that can initially exceed the Eddington limit by orders of magnitude. We argue that the angular momentum of this matter is too low to allow it to attain a disk-like configuration with accretion proceeding at a mildly super-Eddington rate, the excess

energy being carried away by a combination of radiative losses and radially distributed winds. Instead, we propose that the in-falling gas traps accretion energy until it inflates into a weakly-bound, quasi-spherical structure with gas extending nearly to the poles. We study the structure and evolution of such "Zero-Bernoulli accretion" flows (ZEBRAs) as a model for the super- Eddington phase of TDEs. We argue that such flows cannot stop extremely super-Eddington accretion from occurring, and that once the envelope is maximally inflated, any excess accretion energy escapes through the poles in the form of powerful jets. Similar models, including self-gravity, could be applicable to gamma-ray bursts from collapsars and the growth of supermassive black hole seeds inside quasi-stars.

443.08 – Propagating Fluctuations In A Global Accretion Disk Simulation

J. Drew Hogg[1], Christopher S. Reynolds[1], Sean M. O'Neill[2]
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We present an analysis of "propagating fluctuations" in a long, global magnetohydrodynamic (MHD) simulation of the magnetorotational instability (MRI) around a black hole. Viscosity in the standard Shakura and Sunyaev accretion disk (alpha-disk) model is believed to be stochastically generated by turbulence from the MRI, which causes fluctuations in the accretion rate that combine as they propagate to smaller radii. Signatures of propagating fluctuations are thought to have been found in X-ray observations of stellar mass black holes and Kepler observations of AGN, but simulated disks have yet to reproduce this behavior. We find the distribution of accretion rate becomes progressively more skewed at smaller radii and is log-normal at the ISCO in our simulation, and that the coherence of accretion rate fluctuations between two radii is regulated by the viscous time.

443.09 – Propagation of excess mass through a radiatively inefficient accretion disk

David Abarca[1], Aleksander Sadowski[1], Ramesh Narayan[1]
1. Harvard Smithsonian Center for Astrophysics, Cambridge, MA, United States.

Recent observations have shown a 3 Earth Mass cloud of ionized gas en route towards Sgr A*, the black hole at the center of the Galaxy. In the event that G2 or a similar cloud deposits some of its mass in the accretion disk around Sgr A*, we expect this mass to accrete onto the black hole over the course of several years, with observable consequences. We have investigated the process by which excess mass is propagated through a radiatively inefficient accretion flow. We attempt to derive a prescription for the accretion timescale as a function of the initial conditions of the excess mass. We also attempt to predict the fraction of the deposited mass that is accreted and the fraction that is lost to an outflow, as well as the change in the radio luminosity of Sgr A* as a function of time. To derive these estimates, we adopt a toy model in which gas from the cloud is placed in a torus on top of a previously run numerical MHD simulation of a radiatively inefficient accretion disk, and then continue the simulation to monitor the fate of the torus gas. For various scenarios, we track the accretion rate and surface density of the excess matter.

443.11 – Spacetime Geometry Around an Accreting, Spinning Black Hole

Kristina Pardo[1], Edmund Bertschinger[2]
1. Furman University, Greenville, SC, United States. 2. Massachusetts Institute of Technology, Cambridge, MA, United States.

Spinning black holes and their accretion disks are objects of intense study by astrophysicists. While the metric of an isolated spinning black hole has been known for decades, the metric of a spinning black hole built up by accretion has yet to be found. Using the Kerr metric in Doran coordinates, we solved for the motion of a spinning dust cloud, restricted to the equatorial plane, near an uncharged spinning black hole. However, we noticed that our particles would not cross the Cauchy Horizon: this is related to a phenomenon known as mass inflation. By using a coordinate transformation similar to the transformation from Boyer-Lindquist to Doran, we were able to extend our trajectories past the Cauchy Horizon and to the singularity. We used these trajectories to better understand the interior structure of a Kerr black hole. Finally, using this new understanding of the Kerr geometry, we hope to find the approximate metric for an accreting, spinning black hole.

443.12 – Measuring the black hole mass in Ultraluminous X-ray Sources with the X-ray Scaling Method

Insuk Jang[1], Mario Gliozzi[1]
1. George Mason University, Fairfax, VA, United States.

The black hole mass is a crucial parameter to shed light on the physics of accretion. While the presence of stellar mass black holes (sMBHs) in binary systems and supermassive black holes (SMBHs) in the center of galaxies is widely accepted, the very existence of intermediate mass black holes (IMBHs) is still a matter of debate. It has been suggested that this type of black

holes within the mass range of MBH=10^2-10^5 Msun may reside in Ultraluminous X-ray sources (ULXs) which are very bright off nuclear X-ray sources. Recently, a new method to constrain the mass of BH systems, based solely on X-ray data, was successfully used for sMBHs and SMBHs. Since the X-ray emission is thought to be produced by the same process (Comptonization) in all accretion objects, in principle, this method can be applied to estimate the mass of black holes in ULXs. We have carried out a systemic analysis of a sample of 43 ULXs with multiple X-ray observations and applied this novel method. Our preliminary results suggest that ~70% of the sample harbor IMBHs and indicates a good agreement with those derived with different methods present in the literature.

443.13 – Stellar Black Holes in Globular Clusters

Frederic A. Rasio[1], Meagan Morscher[1]
1. Northwestern Univ., Evanston, IL, United States.

We study the formation and evolution of black holes in globular clusters using a Monte Carlo code for stellar dynamics. Our models include stellar evolution for both single and binary stars, as well as all relevant dynamical processes. We find that old globular clusters can retain large numbers (up to hundreds) of stellar black holes all the way to the present, in agreement with other recent theoretical analyses and observations. We explore the implications of these results for the formation of black hole X-ray binaries and merging double black hole binaries in clusters.

444 – Education and Public Outreach Events and Programs

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

444.01 – Skynet Junior Scholars- Sharing the Universe with Blind/Low Vision Youth

Vivian L. Hoette[1], Richard G. Kron[1], Kate Meredith[1], Sue Ann Heatherly[2], Kathryn Williamson[2], Suzanne Gurton[3], Daniel Reichart[4], Joshua Haislip[4]
1. University of Chicago, Williams Bay, WI, United States. 2. National Radio Astronomy Observatory, Green Bank, WV, United States. 3. Astronomical Society of the Pacific, San Francisco, CA, United States. 4. University of North Carolina, Chapel Hill, NC, United States.

Skynet Junior Scholars, a new project funded by the National Science Foundation, aims to engage middle school youth including youth with visual and hearing impairments, in investigating the universe with the same tools professionals use. Project deliverables include: 1) Online access to optical and radio telescopes, data analysis tools, and professional astronomers, 2) An age-appropriate web-based interface for controlling remote telescopes, 3) Inquiry-based standards-aligned instructional modules. From an accessibility perspective, the goal of the Skynet Junior Scholars project is to facilitate independent access to the project deliverables to the greatest extent possible given existing accessibility technologies. In this paper we describe our experience in field-testing SJS activities with 29 blind/low vision youth attending a Lion's Club summer camp. From our observations and preliminary results from pre/post surveys and interviews, we learned that rather than creating a new interest in STEM for these youth, we were instead helping the students satisfy an interest that they already had in these subjects, with our techniques allowing a first direct experience in observational astronomy.

444.02 – Skynet Junior Scholars: Sharing the Universe with Youth

Sue Ann Heatherly[1], Kathryn Williamson[1], Vivian L. Hoette[2], Suzanne Gurton[3], Richard G. Kron[2], Kate Meredith[2], Joshua Haislip[4], Daniel Reichart[4]
1. National Radio Astronomy Observatory, Green Bank, WV, United States. 2. University of Chicago Yerkes Observatory, Williams Bay, WI, United States. 3. Astronomical Society of the Pacific, San Francisco, CA, United States. 4. University of North Carolina, Chapel Hill, NC, United States.

Skynet Junior Scholars is a new National Science Foundation (NSF) funded project designed to engage young explorers in the study of the Universe using the same tools as professionals. Skynet Junior Scholars (SJS) builds on successful precursors that go back to early efforts like Telescopes in Education, through more recent projects like Micro-Observatory. SJS adds to these efforts by tailoring the project to the 4-H program, and by making research quality, multi-wavelength telescopes available. Funded primarily by the NSF, the Skynet Robotic Telescope Network is a growing collection of fully automated or robotic telescopes under the control of software developed by the University of North Carolina. Spanning four continents, Skynet is an easy-to-use, web-based, shared resource between participating colleges, universities, and private individuals. Originally conceived to observe cosmic explosions called gamma-ray bursts, Skynet has now taken over six million images for hundreds of professional astronomers, for thousands of college and university students, for thousands of high school students, and for tens of thousands of middle and elementary school students and members of the general public. Through SJS, middle through high school aged youth enrolled in 4-H or other out-of-school-time programs will use these telescopes, communicate with Skynet STEM professionals, and complete inquiry-based observing activities--all through an interactive web-portal that allows them to share images and data with other young scientists and to publish their results. This paper provides an overview of the SJS project, describes the SJS web-portal and activities in detail, and discusses our scientist engagement efforts and professional development programs. The SJS Telescope User Interface will be demonstrated.

444.03 – Imagine Astronomy at the Rochester Institute of Technology

Valerie Rapson[1], Triana Almeyda[1], Marcus Freeman[1], Davide Lena[1], David Principe[1], Kristina Punzi[1], Benjamin A. Sargent[1], Sravani Vaddi[1], Billy Vazquez[1], Dmitry Vorobiev[1]
1. Rochester Institute of Technology, Rochester, NY, United States.

The Imagine RIT Innovation and Creativity Festival is an annual free event held each year on the campus of the Rochester Institute of Technology (RIT). The purpose of the festival is to showcase the work and research conducted by students and faculty at RIT, and get the public excited about science and technology. For the past three years, graduate students, post-docs and faculty in the Astrophysical Sciences and Technology graduate program at RIT have participated in the festival by showcasing their astronomy research in a fun, interactive and hands on way. We have presented work conducted with various telescopes in the fields of star formation and galaxy evolution. Here, we present our three unique exhibits and the public's reception to each exhibit. We found that interactive games such as astro-trivia, and hands on activities such as building a scale model of the Hubble Space Telescope were the most exciting for visitors. Interactive pieces of the exhibit in general acquired the most attention, whereas posters and videos, despite their pictorial nature, were not as well received. The most

successful piece of our exhibit each year has been solar observing through eclipse glasses and telescopes. Most people who observed the sun at our exhibit were left awe-struck because this was their first experience viewing an astronomical object through a telescope. We plan to improve upon our exhibit by introducing more hands-on activities that will engage the public in current astronomy research at RIT.

444.04 – Dark Skies, Bright Kids! Year 5

Brian Prager[1], Kelsey E. Johnson[1], Loreto D. Barcos-Munoz[1], Rachael Beaton[1], Lauren Bittle[1], H. Jacob Borish[1], Andrew Burkhardt[1], Joanna Corby[1], Guillermo Damke[1], Janice Dean[1], Gregory Dorsey[1], Dawn Graninger[1], Trish Lauck[1], Sandra Liss[1], Apurva Oza[1], Sarah Peacock[1], Charles Romero[1], Kimberly R. Sokal[1], Sabrina Stierwalt[1], Lisa May Walker[1], Trey Wenger[1], Catherine Zucker[1]
1. University of Virginia, Charlottesville, VA, United States.

Our public outreach group Dark Skies, Bright Kids! (DSBK) fosters science literacy in Virginia by bringing a hands-on approach to astronomy that engages children's natural excitement and curiosity. We are an entirely volunteer-run group based out of the Department of Astronomy at the University of Virginia and we enthusiastically utilize astronomy as a 'gateway science.' We create long-term relationships with students during an 8 to 10 week long, after-school astronomy club at under served elementary schools in neighboring counties, and we visited 3 different schools in 2013. Additionally, we organize and participate in science events throughout the community. The fifth year of DSBK was marked by surpassing 10,000 contact hours in Spring 2013 Semester and by ringing in the fall semester with our biggest, most successful star party to date. We hosted the Third Annual Central Virginia Star Party, free and open to the community to encourage families to enjoy astronomy together. Nearly four hundred people of all ages attended, double the number from previous years. Joining with local astronomical societies, we offered an enlightening and exciting night with resources rarely accessible to the public, such as an IR camera and a portable planetarium. With numerous telescopes pointed at the sky, and a beautifully clear night with views of the Milky Way, the International Space Station, and numerous meteors, the star party was a fantastic opportunity to introduce many of our guests to the natural wonders of our night sky and enjoy some of the darkest skies on the eastern seaboard.

444.05 – Astronomy on Tap: A New Event Series for Outreach and Professional Development

Emily L. Rice[1, 2], Megan E. Schwamb[3], Demitri Muna[4]
1. College of Staten Island, Staten Island, NY, United States. 2. American Museum of Natural History, New York, NY, United States. 3. Institute of Astronomy & Astrophysics, Academia Sinica , Taipei, Taiwan. 4. The Ohio State University, Columbus, OH, United States.

We have established an innovative public outreach event series called Astronomy on Tap. The venues, format, timing, and content of the events aim to bring science to the public in an informal, engaging, creative way and to reach a larger, more diverse audience than typical public science lectures at academic and cultural institutions. Each event is held on a weekday evening at a bar and features several short astronomy-related presentations, usually electronic slides with other media formats encouraged. The presenters are typically early-career scientists (grad students, postdocs and new faculty) and occasionally educators, writers, and artists with experience relevant to astronomy. The informal and interactive environment is encouraged by allowing ample time for questions and conversations between presenters and the audience before, during, and after presentations. We also have a designated host who provides introductions, interludes, games, prizes, and give aways. The events serve as professional development by providing opportunities for early-career scientists to practice communication and presentation skills in a decidedly non-academic environment. We have successfully held over ten events in three cities in 2012-2013 and received extremely positive feedback from presenters, attendees, and venue staff. We present key practical considerations for hosting a similar event and share initial evaluation results collected at events in October 2013.

444.06 – Reaching to the Star

Lanika Ruzhitskaya[1], Angela Speck[1], Sean Baldridge[1], Jason Briggs[1]
1. University of Missouri, Columbia, MO, United States.

The 2017 solar eclipse will pass over the Midwest and right over the University of Missouri in Columbia. This event presents us with a wonderful opportunity for science outreach and education programs. In preparation for this event, we use our Coronado solar telescope as a portable solar viewing observatory roving all over our campus. During these solar viewing events, students, faculty and staff have a chance to look through the telescope to discover for themselves-- and learn about-- the most prominent features of the Sun: limb darkening, sunspots, granulations, flares, prominences and filaments. Astronomy undergraduate and graduate students are on hand to answer questions and to hand out leaflets explaining the

science behind these solar features. These solar observations represent excellent opportunities for those who want to know more about the Sun and its role in our lives: from solar activity to global warming; from the formation of the Sun, our planet and the entire Solar System down to the end of our Sun's life. These events also benefit the volunteering students who learn how to explain complicated science concepts in a simple way to the general public. In addition, the portable solar observatory makes people aware about other science talks and events on our campus. These events are a great way to make people on campus aware about the upcoming solar eclipse. Over the course of the next four years we expect to have generated enough interest to be able to accomplish our goal of hosting solar eclipse festivities in August of 2017 in our football stadium in front of a massive crowd of interested observers and potential astronomy students.

444.07 – Radio Jove: Jupiter Radio Astronomy for Citizens

Charles Higgins[1], James R. Thieman[2], Richard Flagg[3], Francisco J. Reyes[4], Jim Sky[5], Wes Greenman[6], Jim Brown[7], Dave Typinski[8], Thomas Ashcraft[9], Andrew Mount[10]
1. Middle Tennessee St. Univ., Murfreesboro, TN, United States. 2. NASA/GSFC, Greenbelt, MD, United States. 3. RF Associates LLC, Honolulu, HI, United States. 4. University of Florida, Gainesville, FL, United States. 5. Radio-Sky Publishing, Captain Cook, HI, United States. 6. Wes Greenman Consultants, Alachua, FL, United States. 7. Hawk's Nest Radio Observatory, Industry, PA, United States. 8. AJ4CO Observatory, High Springs, FL, United States. 9. Heliotown Observatory, Heliotown, NM, United States. 10. Mountain Rest Astronomical Observatory, Mountain Rest, SC, United States.

Radio JOVE is a hands-on educational activity that brings the radio sounds of the Sun, Jupiter, the Milky Way Galaxy, and terrestrial radio noise to students, teachers, and the general public. Participants may build a simple radio telescope kit, make scientific observations, and interact with professional radio observatories in real-time over the Internet. Our website (http://radiojove.gsfc.nasa.gov) includes science information, construction manuals, observing guides, and education resources for teachers and students. Radio Jove is continually expanding its participants with over 1800 kits sold to more than 70 countries worldwide. Recently some of our most dedicated observers have upgraded their Radio Jove antennas to semi-professional observatories. We have spectrographs and wide band antennas, some with 8 MHz bandwidth and some with dual polarization capabilities. In an effort to add to the science literature, these observers are coordinating their efforts to pursue some basic questions about Jupiter's radio emissions (radio source locations, spectral structure, long term changes, etc.). We can compare signal and ionosphere variations using the many Radio Jove observers at different locations. Observers are also working with members of the Long Wavelength Array Station 1 (LWA1) radio telescope to coordinate observations of Jupiter; Radio Jove is planning to make coordinated observations while the Juno Mission is active beginning in 2015. The Radio Jove program is overviewed, its hardware and software are highlighted, recent sample observations are shown, and we demonstrate that we are capable of real citizen science.

444.08 – Modernizing a Public Outreach Department by Harnessing the Power of the Digital Age

Blythe Guvenen[1, 2]
1. National Optical Astronomy Observatory, Tucson, AZ, United States. 2. The University of Arizona, Tucson, AZ, United States.

Amateur astronomers now have access to tools that only professionals had a mere five years ago. As hertz of processing power increase, and as our world becomes increasingly interconnected, planetariums and observatories worldwide have a chance to expand their sphere of influence beyond what was previously possible. As the public program coordinator for the Kitt Peak division of the National Optical Astronomy Observatory, I present a modus operandi for bringing science before the public that incorporates advances in communication, imaging, and automation that will enhance the quality and convenience of public outreach, from visual observing to CCD imaging.

444.09 – Youth for Astronomy & Engineering Program: Engaging Local Families and Partners

Tania Anderson[1], Bonnie Eisenhamer[1], Holly Ryer[1]
1. Space Telescope Science Institute, Baltimore, MD, United States.

Youth for Astronomy and Engineering (YAE) is a program in the Space Telescope Science Institute's Office of Public Outreach. It is designed to engage the local community in science, technology, engineering, and mathematics (STEM). This is accomplished through a series of yearly events such as astronomy and engineering clubs for students, family nights, and professional development for local educators. These events leverage SMD mission science to expose participants to the latest science discoveries (Hubble), new developments in space technology (James Webb), STEM career information, and activities that are representative of the work done by individuals in the astronomical and engineering fields. The YAE program helps provide a progression of opportunities for audiences by attracting and identifying highly-engaged individuals for participation

in more intensive experiences. It also helps increase our impact by creating a network for piloting E/PO products and initiatives at the local level before nationwide release. This poster will highlight the YAE program.

444.10 – Astronomy Education Programs at the Smithsonian National Air and Space Museum

Katie Nagy[1], Genevieve de Messieres[1], Shauna Edson[1]
1. Smithsonian National Air and Space Museum, Washington, DC, United States.

Astronomy educators present the range of astronomy education programming available at the National Air and Space Museum, including the following. In the Phoebe Waterman Haas Public Observatory, visitors use telescopes and other scientific equipment to observe and discuss the Sun, Venus, and other celestial sights in an unstructured, inquiry-based environment. At Discovery Stations throughout the Museum, staff and volunteers engage visitors in hands-on exploration of a wide range of artifacts and teaching materials. Astronomy-related Discovery Stations include Cosmic Survey, an exploration of gravitational lensing using a rubber sheet, spectroscopy using discharge tubes, and several others. Astronomy lectures in the planetarium or IMAX theater, featuring researchers as the speakers, include a full evening of activities: a custom pre-lecture Discovery Station, a handout to help visitors explore the topic in more depth, and evening stargazing at the Public Observatory. Astronomy educators present planetarium shows, including star tours and explorations of recent science news. During Astronomy Chat, an astronomy researcher engages visitors in an informal conversation about science. The goal is to make the public feel welcome in the environment of professional research and to give busy scientists a convenient outreach opportunity. Astronomy educators also recruit, train, and coordinate a corps of volunteers who contribute their efforts to the programming above. The volunteer program has grown significantly since the Public Observatory was built in 2009.

445 – Upper-Level Undergradutae and Graduate Education, Research Opportunities, and Diversity

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

445.01 – A course on professional development for astronomy graduate students

Eileen D. Friel[1]

1. Indiana University, Bloomington, IN, United States.

There is increasingly wide-spread recognition in astronomy that professional training must broaden beyond its traditional approaches to academic classes and research. Many recent community advisory reports, including the National Academy of Sciences Decadal survey, Astro2010, recommend that graduate education accommodate the variety of career paths taken by graduates, taking into account the wide range of activities scientists engage in and the skills necessary to succeed in career options both inside and outside academia and specific scientific disciplines. In response to this need, Indiana University has recently offered a new graduate seminar in astronomy to provide this broader perspective and to prepare students for a variety of career paths after graduate school. The course uses a mixture of class discussion on selected topics supplemented by short readings, activities that prepare students for seeking employment and practice some necessary skills, and discussions with astronomers who have followed a variety of career paths. An important part of the seminar is the practical preparation of complete applications for typical positions students are likely to pursue following graduation, and the revision of these applications to be appropriate for a non-traditional career path. The goal of the course is to make students aware of the many options for careers that will be available to them and the skills that will be important for their success, and to equip students with strategies for following a personally satisfying career path.

445.02 – Raising Awareness in Science Education for Women (RAISE-W)

Jacqueline K. Faherty[1, 2], Mande Holford[3, 2]

1. Carnegie Institution of Washington, Washington, DC, United States. 2. American Museum of Natural History, New York, NY, United States. 3. Hunter College, New York, NY, United States.

Raising Awareness in Science Education for Women (RAISE-W) is a 501c non profit corporation whose mission is to aid in increasing and retaining the number of women - especially underrepresented females - engaged in scientific teaching and research. Initiated by a Protein Chemist and an Astronomer, our ultimate goal has been to develop informational tools and create innovative outreach programs for women across all STEM fields. At present RAISE-W is recruiting women at the undergraduate, graduate, and early career stages to participate in a unique, 1-year, executive coaching program modeled after those used in the business sector.

445.03 – The CAMPARE Program:A New Model Promoting Minority Participation in Astronomy Research and Education

Alexander L. Rudolph[1], Chris D. Impey[2], John H. Bieging[2], Cynthia B. Phillips[3], Jenny Tieu[4], Matthew S. Povich[1]

1. California State Polytechnic Univ., Pomona, CA, United States. 2. University of Arizona, Tucson, AZ, United States. 3. SETI Institute, Mountain View, CA, United States. 4. JPL, Pasadena, CA, United States.

The California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE) program represents a new and innovative kind of research program for undergraduates: one that can effectively carry out the goal of recruiting qualified minority and female students to participate in Astronomy and Planetary Science research opportunities, while mentoring them in a way to maximize the chance that these students will persist in obtaining their undergraduate degrees in STEM fields, and potentially go on to obtain their PhDs or pursue careers in those fields. The members of CAMPARE comprise a network of comprehensive universities and community colleges in Southern California and Arizona (most of which are minority serving institutions), and four major research institutions (University of Arizona Steward Observatory, the SETI Institute, and JPL/Caltech). Most undergraduate research programs focus on a single research institution. By having multiple institutions, we significantly broaden the opportunities for students, both in terms of breadth of research topics and geographical location.

445.04 – Update on the NSF PAARE Project at South Carolina State University

Donald K. Walter[1], Sean D. Brittain[2], Jennifer Cash[1], Dieter Hartmann[2], Kenneth H. Hinkle[3], Steve B. Howell[4], Jeremy R. King[2], Mark D. Leising[2], Kenneth J. Mighell[3], Daniel M. Smith[1]

1. South Carolina State Univ., Orangeburg, SC, United States. 2. Clemson University, Clemson , SC, United States. 3. National Optical Astronomy Observatory, Tucson, AZ, United States. 4. NASA

Ames Research Center, Mountain View, CA, United States.

We summarize the progress made over the past six years of "A Partnership in Observational and Computational Astronomy (POCA)". This NSF-funded project is part of the "Partnerships in Astronomy and Astrophysics Research and Education (PAARE)" program. Our partnership includes South Carolina State University (a Historically Black College/University), Clemson University (a Ph.D. granting institution) and the National Optical Astronomy Observatory. We summarize the results to date of our ongoing ground and space-based study of RV Tauri and Semiregular variables. We also examine our work on two unusual stars, R Coronae Borealis and XX Oph. The research on our Kepler objects is nearing completion and includes new international collaborators. We have developed 2 new cosmology labs and 5 new web simulations in the past year. These are being used in the science classes at South Carolina State University and are available to the community at our website listed below. Our success and the challenge of recruiting and retaining underrepresented students into the field as physics majors at South Carolina State University is reviewed. We recently graduated from Clemson a POCA student with a M.S. in astronomy who has since continued on for a Ph.D. in a related field, while another underrepresented student continues toward her Ph.D. in astronomy. Support for the POCA project is provided by the NSF PAARE program to South Carolina State University under award AST-0750814 as well as resources and support provided by Clemson University and the National Optical Astronomy Observatory. Support for the Kepler observations is provided by NASA to South Carolina State University under awards NNX11AB82G and NNX13AC24G. Additional details can be found at: http://physics.scsu.edu/paare/

445.05 – Stepping Stones to Research: Providing Pipelines from Middle School through PhD

Jacob Noel-Storr[1], Stefi A. Baum[1]
1. Rochester Inst. Of Technology, Rochester, NY, United States.
Contributing teams: RIT Insight Lab SSR Team, Chester F. Carlson Center for Imaging Science Faculty

We present a decade's worth of strategies designed to promote and provide "Stepping Stones to Research" to provide a realistic pipeline of educational opportunities, with multiple gateways and exit points, for students moving towards STEM careers along the "STEM pipeline". We also illustrate how the Stepping Stones are designed to incidentally co-inside with related external opportunities through which we can also guide and support our mentees on their paths. We present programs such as middle school family science programs, high school research opportunities, high school internships, undergraduate research pathways, research experiences for undergraduates, and other opportunities. We will highlight the presentations being made at this very meeting -- from the first presentation of a high school student, to a dissertation presentation of a PhD graduate -- that have benefited from this stepping stone principle. We also reflect on the essential nature of building a "researcher-trust", even as a young student, of advocates and mentors who can support the continuation of a scientific career.

445.06 – The 2013 Summer Undergraduate Research Internship Program at the Pisgah Astronomical Research Institute

Michael W. Castelaz[1], J. D. Cline[1], Christi Whitworth[1], David Clavier[1], Thurburn Barker[1]
1. Pisgah Astronomical Research Inst., Rosman, NC, United States.

Pisgah Astronomical Research Institute (PARI) offers summer undergraduate research internships. PARI has received support for the internships from the EMC Corporation, private donations, private foundations, and through a collaboration with the Pisgah Astronomical Research and Education Center of the University of North Carolina – Asheville. The internship program began in 2001 with 4 students. This year 10 funded students participated. Mentors for the interns include PARI's Directors of Science, Education, and Information Technology and visiting faculty who are members of the PARI Research Faculty Affiliate program. Students work with mentors on radio and optical astronomy research, electrical engineering for robotic control of instruments, software development for instrument control and and science education by developing curricula and multimedia and teaching high school students in summer programs at PARI. At the end of the summer interns write a paper about their research which is published in the PARI Summer Student Proceedings. Students are encouraged to present their research at AAS Meetings. We will present a summary of specific research conducted by the students with their mentors.

445.07 – The Contributions of the WIYN Observatory to Undergraduate Education

Eric Hooper[1, 2]
1. WIYN Observatory, Tucson, AZ, United States. 2. Univ. of Wisconsin-Madison, Madison, WI, United States.
Contributing teams: WIYN Consortium

Over its nearly 20 year history the WIYN Observatory has provided crucial data for numerous undergraduate research projects at the partner institutions (University of Wisconsin-Madison, Indiana University, and Yale University) plus others who access the telescope via national time from NOAO. WIYN and its instruments have served both undergraduates who are local to each institution, as well as those who have a temporary tenure as Research Experience for Undergraduates (REU)

students. The topics of this work range widely, and only a few examples are listed here. Numerous studies of stars have been undertaken by undergraduates, from rotation velocities of pre-main sequence stars (Rhode et al.) to dynamical heating mechanisms in open clusters (Friel et al.). Extragalactic investigations range from a study of cold ISM in galaxies near the centers of rich clusters (Gallagher & Hooper, et al.) to the stellar populations of post-starburst galaxies hosting low-level AGN (Wolf & Hooper, et al.). Students have made wide use of WIYN's long established suite of facility instruments, which currently includes the Hydra multi-object fiber spectrograph, the SparsePak integral field unit fiber spectrograph, and the WHIRC near-infrared imager. A current undergraduate is a key player in final laboratory testing of two new integral field units that will come to WIYN soon. Finally, the new large format imager pODI currently is in science operation, soon to be followed by an upgrade to nearly four times the current imaging area, a powerful tool that will join the others in contributing to undergraduate research and education. This presentation is a continuation of the overview of WIYN contributions to education that began with a discussion of graduate education at the Indianapolis AAS (Hooper, AAS Meeting #222, #214.23).

445.08 – Research Experience for Undergraduate and Early College High School Students at University of Texas at El Paso

Omar Medrano[1], Emmanuel Gonzalez[1], Paul A. Mason[1]
1. University of Texas at El Paso, El Paso, TX, United States.

A program of astrophysics research, education, and outreach to high school students recently developed at the University of Texas at El Paso (UTEP) is described. Undergraduate students engage in observational research at McDonald Observatory, using the 2.1 and 2.7-m telescopes. An observational astronomy laboratory was developed for undergraduate majors. In addition, UTEP physics majors mentored area early-college high school students for hundreds of hours of summer research experience. UTEP and UT-Austin are partner institutions and this program is funded by NSF grant 0958783.

445.09 – The Lowell Observatory Predoctoral Fellowship Program

Lisa A. Prato[1], Evgenya Shkolnik[1]
1. Lowell Observatory, Flagstaff, AZ, United States.

Lowell Observatory is pleased to solicit applications for our Predoctoral Fellowship Program. Now beginning its seventh year, this program is designed to provide unique research opportunities to graduate students in good standing, currently enrolled at Ph.D. granting institutions. Lowell staff research spans a wide range of topics, from astronomical instrumentation, to icy bodies in our solar system, exoplanet science, stellar populations, star formation, and dwarf galaxies. The Observatory's new 4.3 meter Discovery Channel Telescope has successfully begun science operations and we anticipate the commissioning of several new instruments in 2014, making this a particularly exciting time to do research at Lowell. Student research is expected to lead to a thesis dissertation appropriate for graduation at the doctoral level at the student's home institution. The Observatory provides competitive compensation and full benefits to student scholars. For more information, see http://www2.lowell.edu/rsch/predoc.php and links therein. Applications for Fall 2014 are due by May 1, 2014.

445.10 – The Cerro Tololo Inter-American Observatory Summer Student Programs in La Serena, Chile

Catherine C. Kaleida[1], Chris Smith[1], Nicole S. Van Der Bliek[1], David James[1]
1. Cerro Tololo Inter-American Observatory, La Serena, IV, Chile.

The Cerro Tololo Inter-American Observatory (CTIO) offers positions for U.S. and Chilean student interns during the Chilean summer months of January-March (northern winter semester) at the CTIO offices in La Serena, Chile. CTIO is part of the National Optical Astronomy Observatory (NOAO) of the United States, focused on the development of astronomy in the southern hemisphere. Six undergraduate research assistantships are offered for U.S. physics and astronomy undergraduate students through the NSF-funded Research Experiences for Undergraduates (REU) program. The CTIO-funded Prácticas de Investigación en Astronomía (PIA) program is run concurrently with the REU program, and offers two research assistantships for Chilean undergraduate or 1st or 2nd year masters students, also at the CTIO offices in La Serena, Chile. The CTIO REU and PIA programs provide exceptional opportunities for students considering a career in astronomy to engage in substantive research activities with scientists working at the forefront of contemporary astrophysics. Student participants work on specific research projects in close collaboration with members of the CTIO scientific and technical staff, such as galaxy clusters, gravitational lensing, supernovae, planetary nebulae, stellar populations, star clusters, star formation, variable stars and interstellar medium. The CTIO REU and PIA programs emphasize observational techniques and provide opportunities for direct observational experience using CTIO's state-of-the-art telescopes and instrumentation. The programs run for 10 weeks, from mid-January to the end of March. A two-night observing run on Cerro Tololo and a field trip to another observatory in Chile are included for students of both programs. These positions are full time, and those selected will receive a modest stipend and subsidized housing on the grounds of the offices of CTIO in La Serena, as well as travel costs to and from La Serena. In addition, the students have the opportunity attend the American Astronomical Society (AAS) winter meeting to present their research the year following the program.

445.11 – AstroCom NYC: A Partnership Between Astronomers at CUNY, AMNH, and Columbia University

Timothy Paglione[1, 4], K.E. S. Ford[2, 4], Dennis Robbins[3], Mordecai-Mark Mac Low[4], Marcel A. Agueros[5]

1. York College, CUNY, Jamaica, NY, United States. 2. Borough Manhattan Comm. College, CUNY, New York, NY, United States. 3. Hunter College, CUNY, New York, NY, United States. 4. AMNH, New York, NY, United States. 5. Columbia Univ., New York, NY, United States.

AstroCom NYC is a new program designed to improve urban minority student access to opportunities in astrophysical research by greatly enhancing partnerships between research astronomers in New York City. The partners are minority serving institutions of the City University of New York, and the astrophysics research departments of the American Museum of Natural History and Columbia. AstroCom NYC provides centralized, personalized mentoring as well as financial and academic support, to CUNY undergraduates throughout their studies, plus the resources and opportunities to further CUNY faculty research with students. The goal is that students' residency at AMNH helps them build a sense of belonging in the field, and inspires and prepares them for graduate study. AstroCom NYC prepares students for research with a rigorous Methods of Scientific Research course developed specifically to this purpose, a laptop, a research mentor, career mentor, involvement in Columbia outreach activities, scholarships and stipends, Metrocards, and regular assessment for maximum effectiveness. Stipends in part alleviate the burdens at home typical for CUNY students so they may concentrate on their academic success. AMNH serves as the central hub for our faculty and students, who are otherwise dispersed among all five boroughs of the City. With our first cohort we experienced the expected challenges from their diverse preparedness, but also far greater than anticipated challenges in scheduling, academic advisement, and molding their expectations. We review Year 1 operations and outcomes, as well as plans for Year 2, when our current students progress to be peer mentors.

445.12 – Promoting the Understanding of Scientific Reasoning, Mathematical Modeling and Data Analysis: A Course for Astrophysics Majors

Dennis Robbins[1, 2], Saavik Ford[3, 1]

1. Hunter College (CUNY), New York City, NY, United States. 2. American Museum of Natural History, New York City, NY, United States. 3. Borough of Manhattan Community College (CUNY), New York City, NY, United States.

The NSF-supported "AstroCom NYC" program, a collaboration of the City University of New York, American Museum of Natural History (AMNH), and Columbia University has the explicit goal of increasing the participation of underrepresented minorities in astronomy and astrophysics by providing pedagogical mentoring and research experiences to undergraduate students. To supplement AstroCom scholars' undergraduate course work, and as a gateway to summer astrophysics research opportunities, we implemented a course called "Methods of Scientific Research" (MSR). The semester-long MSR course emphasizes the study of data using computers and other digital tools in a laboratory environment that encourages collaborative and active learning. We enroll early physical science majors and deliberately seek to inculcate habits of mind needed for science research, including assigning physical meaning to variables and measurements; engaging in mathematical modeling; quantifying error; eliminating bias; proposing hypotheses; creating predictions; testing predictions. Using laptop computers interfaced with probeware, students collect and analyze data using graphing software. Students study concepts such as motion, temperature, magnetism, electricity, gas pressure, and force with open-ended investigations where large data sets can be readily collected and replicated during a course meeting. Students are guided to examine data for patterns and trends, to make meaning of descriptive statistics such as means, standard deviations, maximum and minimum values, correlation coefficients and root mean square error values, and in general to understand, judge, and describe the studied phenomena based on data. A secondary goal of the course is to familiarize students with the facilities at AMNH, where they will do summer research as part of AstroCom NYC, in an effort to build a sense of belonging and to help them begin to self-identify as a scientist. We will discuss some our activities and present our ideas on encouraging habits of mind needed in astrophysics research.

445.13 – Updates from Astrobites: The Astro-ph Reader's Digest

Benjamin Montet[1], Nora Elisa Chisari[5], Jessica Donaldson[4], Courtney D. Dressing[3], Maria Drout[3], Christopher Faesi[3], Joshua T. Fuchs[6], Susanna Kohler[2], Elizabeth Lovegrove[8], Elisabeth A. Mills[11], Erika Nesvold[10], Elisabeth R. Newton[3], Alice Olmstead[4], Justin A. Vasel[9], Lauren M. Weiss[7]

1. California Institute of Technology, Pasadena, CA, United States. 2. University of Colorado, Boulder, CO, United States. 3. Harvard University, Cambridge, MA, United States. 4. University of Maryland, College Park, College Park, MD, United States. 5. Princeton University, Princeton, NJ, United States. 6. University of North Carolina, Chapel Hill, NC, United States. 7. University of California, Berkeley, Berkeley, CA, United States. 8. University of California, Santa Cruz, Santa Cruz, CA, United States. 9. University of Minnesota Duluth, Duluth, MN, United States. 10.

University of Maryland, Baltimore County, Baltimore, MD, United States. 11. National Radio Astronomy Observatory, Socorro, NM, United States.
Contributing teams: The Astrobites Team

Astrobites (http://astrobites.com) is a daily blog aimed at undergraduates interested in astrophysical research and written by a team of graduate students located at diverse institutions across the United States. Primarily, we present journal articles recently posted to astro-ph in a brief format that is accessible to anyone with a general background in the physical sciences, including readers who are not yet familiar with the astrophysical literature. Special posts offer career guidance for undergraduates (e.g. applying for an NSF graduate fellowship) and describe personal experiences (e.g. attending an astronomy summer school). We present recent readership statistics and potential methods for incorporating Astrobites into the classroom. We also discuss the Astrobites format across multiple social media platforms, including the newly launched Astroplots, and highlight our recent work organizing the annual "Communicating Science" workshop for graduate students.

445.14 – Tablet Computing Devices to Bridge the Gap Between Planetarium and Night Sky

Jason P. Smolinski[1]
1. State University of New York College at Oneonta, Oneonta, NY, United States.

While planetariums conveniently allow students to experience the night sky in an indoor setting, and often include digital overlays of labels, images, and coordinates, many students still struggle to translate this visualization into reality when viewing the night sky outdoors. This study studies the potential for tablet computing devices to help bridge that gap. Specifically, topics are investigated that are typically taught to upper level astronomy students, including coordinate systems and advanced aspects of the celestial sphere.

446 – Observatories for Education and Public Outreach

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

446.01 – CSU's MWV Observatory: A Facility for Research, Education and Outreach

John Hood[1], Nicholas D. Carpenter[1], Cameron B. McCarty[1], James H. Samford[1], Michael Johnson[1], Andrew W. Puckett[1], Rosa N. Williams[1], Shawn T. Cruzen[1]
1. Columbus State University, Columbus, GA, United States.

The Mead Westvaco Observatory (MWVO), located in Columbus State University's Coca-Cola Space Science Center, is dedicated to education and research in astronomy through hands-on engagement and public participation. The MWVO has recently received funding to upgrade from a 16-inch Meade LX-200 telescope to a PlaneWave CDK 24-inch Corrected Dall-Kirkham Astrograph telescope. This and other technological upgrades will allow this observatory to stream live webcasts for astronomical events, allowing a worldwide public audience to become a part of the growing astronomical community. This poster will explain the upgrades that are currently in progress as well as the results from the current calibrations. The goal of these upgrades is to provide facilities capable of both research-class projects and widespread use in education and public outreach. We will present our initial calibration and tests of the observatory equipment, as well as its use in webcasts of astronomical events, in solar observing through the use of specialized piggy-backed telescopes, and in research into such topics as asteroids, planetary and nebula imaging. We will describe a pilot research project on asteroid orbit refinement and light curves, to be carried out by Columbus State University students. We will also outline many of the K-12 educational and public outreach activities we have designed for these facilities. Support and funding for the acquisition and installation of the new PlaneWave CDK 24 has been provided by the International Museum and Library Services via the Museums for America Award.

446.02 – The Stocker AstroScience Center at Florida International University

James R. Webb[1]
1. Florida International Univ., Miami, FL, United States.

The new Stocker AstroScience Center located on the MMC campus at Florida International University in Miami Florida represents a unique facility for STEM education that arose from a combination of private, State and university funding. The building, completed in the fall of 2013, contains some unique spaces designed not only to educate, but also to inspire students interested in science and space exploration. The observatory consists of a 4-story building (3 floors) with a 24" ACE automated telescope in an Ash dome, and an observing platform above surrounding buildings. Some of the unique features of the observatory include an entrance/exhibition hall with a 6-ft glass tile floor mural linking the Florida climate to space travel, a state-of-the art telescope control that looks like a starship bridge, and displays such as "Music from the universe". The observatory will also be the focus of our extensive public outreach program that is entering its 20 year.

446.03 – The Center for Advanced Radio Astronomy: Graduates, Undergraduates and High School Students Engaged in the Exploration of Astrophysics

Andy Miller[2], Fredrick A. Jenet[1]
1. University of Texas-Brownsville, Brownsville, TX, United States. 2. Saint Joseph Academy, Brownsville, TX, United States.

The Center for Advanced Radio Astronomy (CARA) is a part of the University of Texas system located in Brownsville, Texas. Under the umbrella of CARA is the Arecibo Remote Command Center (ARCC). The ARCC is a virtual control room where researchers and students (graduate, undergraduate, and local high school students) control and take data utilizing the Arecibo Observatory, the Green Bank Telescope, and the Long Wavelength Array. This poster presents a general outline of CARA programs and recent accomplishments—including on-going pulsar discoveries, the expansion of the Low Frequency All Sky Monitor (LoFASM) to four sites across North America, and the graduation of our second cohort of ARCC Scholars.

446.04 – Design and Construction of a Polarimeter for Small Telescopes

Gregory A. Topasna[1], Daniela M. Topasna[1]
1. Virginia Military Inst., Lexington, VA, United States.

A polarimeter of simple design and construction for a small research telescope is presented. The polarimeter is the common dual-beam design utilizing a rotatable half-wave plate and Wollaston prism, which splits starlight into its ordinary and extraordinary rays with a 0.5 degree divergence angle. These rays are then imaged on a CCD detector after they have passed through a broadband filter. The usable field of view is ~ 10 arcminutes and the operational range of the instrument is 400 nm - 700 nm. Measurements of unpolarized standard stars demonstrate that the instrumental polarization is on the order of 0.05% or less. Measurements of polarized standard stars indicate agreement with published values to within 0.2% for the degree of polarization and to within 1 degree or less for the position angle. The polarimeter was constructed using

off-the-shelf components and only a minimal amount of machining was required for its construction.

447 – Astronomy Programs and Resources for High School Students and Teachers

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

447.01 – Implementation of the 2013 Astro-Science Workshop, a Hands-on High Altitude Ballooning Program at the Adler Planetarium

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1. Adler Planetarium, Chicago, IL, United States. 2. Illinois Institute of Technology, Chicago, IL, United States.

For the past 7 years, high school students participating in the Astro-Science Workshop at the Adler Planetarium have been able to access the extreme environment of near space (approximately 30 km altitude) using high altitude balloons. Taking a hands-on approach the program has allowed students to design, build, and launch their own experiments with programming based at the Adler Planetarium. During flight, payloads are subjected to temperatures of around -65° C, atmospheric pressure of only 1% that at sea level, and cosmic radiation levels more than 60 times the surface background. In some ways, conditions at these altitudes are much like those at the surface of Mars, providing students with the opportunity to build and operate real-world analogs of interplanetary probes. We have found that this hands-on, student-driven research-based program is enhanced by implementing classroom and lab activities as well as by incorporating instruction and collaboration with research professionals currently active in the field of astronomy. We present the steps taken to implement the 2013 Astro-Science Workshop at the Adler Planetarium with a focus on daily instruction and operations planning and launch preparation.

447.02 – Developing a Curriculum for Remote Research Mentoring of Virginia High School Students

William J. Dirienzo[1], Joanna Corby[1], Rachael Beaton[1], Loreto D. Barcos-Munoz[1], Kristen M. Jones[1], Tim Pennucci[1]
1. University of Virginia, Charlottesville, VA, United States.

Graduate students at the University of Virginia (UVa) are volunteering as research advisors on astronomy projects for Virginia's science and technology high schools. Over five years, we have worked with more than a dozen students through a research class at Central Virginia Governor's School for Science and Technology in Lynchburg and two students last year at Roanoke Valley Governor's School in Roanoke to develop an astronomy research curriculum that teaches background concepts and terminology, guides students in data analysis, and prepares them to present material in poster and oral forums. Because both schools are far from UVa in Charlottesville, the program operates remotely; graduate advisors and high school students interact through "virtual" means, establishing a successful framework for meaningful remote mentoring. In the current year, four students will complete projects on astrophysical topics including megamasers and astrochemistry using data taken by the Robert C. Byrd Green Bank Telescope (GBT). Previous topics also include pulsar searches, extended green object (EGO) searches, and the X-ray properties of YSOs in the Carina complex. All four students this year will receive hands-on experience in handling GBT data. The current projects are components of larger research efforts by graduate student and professional level researchers, so that the projects contribute to high-level projects only possible with the GBT. This stands as a rare outreach program that uses the principle of "deliberative practice" to train high school students in the development of skills that are crucial to success in science. Furthermore, it provides graduate students with an opportunity to plan and advise research projects, developing a skill set that is required in more advanced academic positions. Our poster discusses the implementation of our online curriculum in two distinct class settings and highlights the students' research contributions.

447.03 – WorldWide Telescope in High School Astronomy Competitions

Ana-Maria Constantin[1], Alyssa A. Goodman[2], Patricia S. Udomprasert[3]
1. Harvard University, Cambridge, MA, United States. 2. Harvard Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. Harvard Smithsonian Center for Astrophysics, Cambridge, MA, United States.

This project aims to improve astronomy education at the high school level, and to increase awareness in astronomy for pre-university students, on an international scale. In 2013, the WorldWide Telescope Ambassadors Program began a collaboration with the International Olympiad in Astronomy and Astrophysics (IOAA), which was held in the city of Volos, Greece in August 2013. Now at its VIIth edition, IOAA is the largest annual astronomy competition for high school students, and it consists of one team task and three individual ones – Theoretical, Data Analysis, and Observational. Each of the participating countries (35 in 2013, compared to 21 in 2007) is responsible for selecting up to five representative students for the International round. IOAA is meant to promote future collaborations between these students, and to encourage friendships inside a global scientific community. Ana-Maria Constantin, a current Harvard undergraduate student and a

former medalist of IOAA, represented WorldWide Telescope Ambassadors in Greece by giving a talk on the advantages of using WWT as a tool for research and education. As a result, the President and the International Board of the Olympiad have expressed support for including WWT in the competition for future editions. WWTA is working with the Organizing Board for next year's competition in Romania, to include WWT as a testing tool. This poster will summarize key points from the WWTA presentation in Greece, present ideas for WWT-based activities in future IOAA competitions, and outline plans for new collaborations from representatives of Sri Lanka, Poland, Bangladesh, and Colombia. Given the positive feedback we have received after the presentation in Greece, we are also considering future implementations of WWT in summer research camps for high school students, such as the Summer Science Program.

447.04 – Multiwavelength Astronomy Modules for High School Students

Christie Thomas[1], Julia Brazas[1], Steven Lane[1], Donald G. York[1]
1. The University of Chicago, Chicago, IL, United States.

The University of Chicago Multiwavelength Astronomy modules are web-based lessons covering the history, science, tools, and impact of astronomy across the wavebands, from gamma ray to infrared. Each waveband includes four lessons addressing one aspect of its development. The lessons are narrated by a historical docent or practicing scientist who contributed to a scientific discovery or instrument design significant to astronomical progress. The process of building each lesson began with an interview conducted with the scientist, or the consultation of a memoir or oral history transcript for historical docents. The source was then excerpted to develop a lesson and supplemented by archival material from the University of Chicago Library and other archives; NASA media; and participant contributed photographs, light curves, and spectra. Practicing educators also participated in the lesson development and evaluation. In July 2013, the University of Chicago sponsored 9 teachers and 15 students to participate in a STEM education program designed to engage participants as co-learners as they used the Multiwavelength Astronomy lessons in conjunction with talks given by the participating scientists. Teachers also practiced implementation of the resources with students and designed authentic research activities that make use of NASA mission data, which were undertaken as mini-research projects by student teams during the course of the program. This poster will introduce the Multiwavelength Astronomy web modules; highlight educator experiences in their use with high school audiences; and analyze the module development process, framing the benefits to and contributions of each of the stakeholders including practicing astronomers in research and space centers, high school science educators, high school students, University libraries and archives, and the NASA Science Mission Directorate. The development of these resources, and the summer professional development workshops were funded by NASA EPOESS awards. The modules can be accessed at http://ecuip.lib.uchicago.edu/multiwavelength-astronomy.

448 – Astronomy Education Research
Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

448.01 – STEMdex: A Searchable Database of Education Research for Our Community

Carolyn Brinkworth[1], Michelle Nichols-Yehling[2], Lindsay Bartolone[2], Jacob Llamas[1], Megan Crane[1], Ann Martin[4], Mathew Wenger[3], Gordon K. Squires[1], Robert L. Hurt[1]
1. Caltech, Pasadena, CA, United States. 2. Adler Planetarium, Chicago, CA, United States. 3. University of Arizona, Arizona, CA, United States. 4. NASA Langley, Virginia, CA, United States.

STEMdex is a new resource for the astronomy Education and Outreach community, designed to improve our community's knowledge of the published literature pertinent to our work. While we all understand that it is important to base our practice on sound research, there are currently 801 peer-reviewed education journals in existence, and members of our community are hard pressed to cover all the published literature. STEMdex consolidates the research relevant to EPO work into a single searchable database, with summaries written by astronomy educators and posted for the entire community to use. The database will ultimately include research across the spectrum of astronomy education, including formal and informal education, outreach, grades K-16, pedagogy, evaluation and many other topics. The site is currently under development, but we have had significant interest from the community, and have a team of 19 EPO professionals and community volunteers from 14 different institutions signed up to contribute to the project. The STEMdex site can be found at stemdex.ipac.caltech.edu.

448.02 – Evaluation of a College Freshman Diversity Research Program in Astronomy

Michael J. Tremmel[1], Sarah M. Garner[1], Sarah J. Schmidt[2], John P. Wisniewski[3], Eric Agol[1]
1. University of Washington, Seattle, WA, United States. 2. The Ohio State University, Columbus, OH, United States. 3. University of Oklahoma, Norman, OK, United States.

Graduate students in the astronomy department at the University of Washington began the Pre-Major in Astronomy Program (Pre-MAP) after recognizing that underrepresented students in STEM fields are not well retained after their transition from high school. Pre-MAP is a research and mentoring program that begins with a keystone seminar where they learn astronomical research techniques that they apply to research projects conducted in small groups. Students also receive one-on-one mentoring and peer support for the duration of the academic year and beyond. Successful Pre-MAP students have declared astronomy and physics majors, expanded their research projects beyond the fall quarter, presented posters at the UW Undergraduate Research Symposium, and received research fellowships and summer internships. Here we examine the success of the program in attracting underrepresented minorities and in facilitating better STEM retention and academic performance among incoming UW students. We use the University of Washington Student Database to study both the performance of Pre-MAP students and the overall UW student body over the past 8 years. We show that Pre-MAP students are generally more diverse than the overall UW population and also come in with a variety of different math backgrounds, which we show to be an important factor on STEM performance for the overall UW population. We find that that Pre-MAP students are both more academically successful and more likely to graduate in STEM fields than their UW peers, regardless of initial math placement.

448.03 – A Research-Informed Approach to Teaching About Exoplanet Detection in STEM Classrooms

Gina Brissenden[1], Colin S. Wallace[1], Edward E. Prather[1], Wesley A. Traub[2], W. M. Greene[2], Anya A. Biferno[2]
1. Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, Tucson, AZ, United States. 2. NASA Exoplanet Exploration Program (ExEP), Jet Propulsion Laboratory, Pasadena, CA, United States.

JPL's NASA Exoplanet Exploration Program's (ExEP) Public Engagement Program, in collaboration with the Center for Astronomy Education (CAE), is engaged in a research and curriculum development program to bring the science of exoplanet detection into STEM classrooms. In recent years, there has been a significant increase in the number of astronomers pursuing research related to exoplanets, along with a significant increase in interest amongst students and the general public regarding the topic of exoplanets. CAE has previously developed a curriculum unit (including Think-Pair-Share questions and a Lecture-Tutorial) to help students develop a deeper understanding of the Doppler method for detecting extrasolar planets. To date, there is a nearly nonexistent research base on students' conceptual and reasoning difficulties related to the science of the transit and gravitational microlensing methods for detecting extrasolar planets. Appropriate for physical science classrooms from middle school to the introductory college level, the learner-centered active engagement activities we are developing are going through an iterative research and assessment process to ensure that they enable students to achieve

increased conceptual understandings and reasoning skills in these areas. In this talk, we will report on our development process for two new Lecture-Tutorials that help students learn about the transit and gravitational microlensing methods for finding exoplanets.

448.04 – Worldviews of Introductory Astronomy Students

Chrystin Green[1], Colin S. Wallace[2], Gina Brissenden[2], Edward E. Prather[2]
1. California State Polytechnic University, Pomona, Pomona, CA, United States. 2. Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, Tucson, AZ, United States.
Contributing teams: Collaboration of Astronomy Teaching Scholars (CATS)

As a part of a larger project to study introductory astronomy students' worldviews and beliefs about the role of science in society, we examined students' responses to a subset of questions designed to probe students' worldviews and how they change after taking a general education, introductory astronomy course (Astro 101). Specifically, we looked at about 400 students' choices for the top ten scientific discoveries in the past 150 years. We collected students' rankings twice: Once at the start of their Astro 101 class and once at the end. We created a rubric that we used to categorize the responses and we established the inter-rater reliability of the rubric. Our results show that students preferentially answered with topics related to technology and health and medicine. The data also show that there was an increase, pre- to post-instruction, in the number of responses in the technology and health and medicine categories. We also saw a decrease in the number of responses in the science category. These results imply that an aspect of the course specifically implemented to broaden student's views on science in relation to society was successful. This material is based upon work supported by the National Science Foundation under Grant No. AST-0847170, for the California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE) program. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

448.05 – Investigating Science Literacy: Students' Conceptions of Radiation

James Romine[1], Sanlyn Buxner[1], Chris D. Impey[1], Megan N. Nieberding[1], Jessie C. Antonellis[2]
1. Steward Observatory, University of Arizona, Tucson, AZ, United States. 2. Little Priest Tribal College, Winnebago, NE, United States.
Contributing teams: Collaborations of Astronomy Teaching Scholars (CATS), Steward Observatory, University of Arizona

This study is part of a larger investigation of students' science literacy in which we have been collecting survey data from undergraduate students enrolled in introductory science courses from 1980-2013. The overall survey asks students questions about basic topics in science and technology. We present results from the analysis of students' open-ended responses to the question "What is radiation?" Our findings show that a substantial number of students' perceptions of radiation are focused on the dangers of radiation and less on the applications. A large fraction of students correctly identified radiation as energy or light, although they expressed the misconception that only part of the electromagnetic spectrum counted as radiation. Overall, students expressed a number of misconceptions about the sources and uses of radiation although over 80% know that radiation can occur naturally or be man made. We present how these findings relate to other large trends from the survey. This material is based in part upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

448.06 – Exploring the Potential of the Massive, Open, Online Astronomy Course

Carmen Austin[1], Chris D. Impey[1], Mathew Wenger[1]
1. University of Arizona, Tucson, AZ, United States.

Astronomy: State of the Art is a massive, open, online course (MOOC) in astronomy. Course content was released weekly, over 7 weeks, in the spring of 2013. More than 10 hours of video lectures were produced and deployed along with supplementary readings, podcasts, and realtime Q&A sessions with professor Chris Impey. All content is still available online as a self-paced course. Over 5,000 students have enrolled in the course through the online course platform Udemy. This poster presents student engagement data, and a discussion of lessons learned and opportunities for future improvement.

448.07 – Learning Curve for Teaching Constellations in a Planetarium

Eric G. Hintz[1], Nicole Smith[1], J. W. Moody[1], Denise C. Stephens[1], Michael D. Joner[1], Maureen Hintz[1], Jeannette Lawler[1], Michael Jones[1], Nathan Bench[1]
1. Brigham Young Univ., Provo, UT, United States.

As part of a larger project we have examined how students learn constellations in a planetarium environment. Students in our introductory descriptive astronomy class were given a 50 object quiz before any instruction. This quiz includes 30 constellations, 17 bright stars, two star clusters, and the Orion Nebula. In addition we gathered a small set of demographic information. After the initial quiz we tracked student scores through the semester to see how long it took for them to learn all 50 objects. We also plan to give a follow-up constellation quiz to students who have previously taken the quiz to test for retention. This will cover a time line for 6 months up to 4 years. We will present our early results from this study. This data will also be used as a baseline for a study of Head Mounted Displays to teach a deaf audience in a planetarium. This work is partially supported by funding from the National Science Foundation grant IIS-1124548 and the Sorenson Foundation.

448.08 – Driven to Distraction: Does the Infamous Earth Shadow Distractor Divert Student Attention in the Cause of the Phases of the Moon Question?

Daniel B. Caton[1]
1. Appalachian State Univ., Boone, NC, United States.

The concept of the cause of the phases of the Moon is one that is well known to be a problem for astronomy students, with a large fraction thinking incorrectly that the phases are caused by the shadow of the Earth. I have typically repeated this question from the first exam in the two-semester Introductory Astronomy course, through the final exam of the second semester, for a total of 8 appearances. It occurred to me that the inclusion of the shadow distractor in these multiple choice questions may actually reinforce the misconception by repeatedly distracting the student to the familiar but wrong answer. I am running an experiment to see if this is happening. I am giving different forms of the question to half the class for exams 2 and 3 of the first semester, exams 1-3 of the second, with half the class not getting the shadow distractor. I then am offering the shadow distractor to the whole class for the two semesters' final exams. The early results of this experiment will be discussed.

448.09 – CosmoQuest Year 2: Citizen Science Progress, Motivations, and Education

Nicole E. Gugliucci[1], Pamela L. Gay[1], Irene Antonenko[2], Georgia Bracey[1], Kathy Costello[1], Cory Lehan[1], Joseph Moore[1], Ellen Reilly[1], Stuart J. Robbins[3], Britney E. Schmidt[4]
1. Southern Illinois University Edwardsville, Edwardsville, IL, United States. 2. Planetary Institute of Toronto, Toronto, ON, Canada. 3. Southwest Research Institute, Boulder, CO, United States. 4. University of Texas, Austin, TX, United States.
Contributing teams: CosmoQuest Collaboration

The CosmoQuest citizen science virtual research facility has wrapped up its second year of operations. With projects mapping the surfaces of the Moon, Mercury, and asteroid Vesta, citizen scientists have marked over 2 million craters as well as other surface features. Analysis of the mapping results show that citizen scientists map high resolution features as well as expert crater markers within a small margin of error. We've undertaken a study of citizen science motivations with our users, and find that an interest in astronomy and a desire to contribute new knowledge as primary motivating factors. Ten percent of users surveyed list learning or teaching science as the primary motivating factor. A full analysis of this survey will be presented. Along those lines, the CosmoQuest education team has developed a second middle school educational unit to align with its citizen science projects. In-Vesta-Gate explores asteroid science and is in the trial stage, while we report on several teacher professional development opportunities with Terraluna, a Moon-focused educational unit developed last year. We've also taken the CosmoQuest citizen science on the road and outside the website, having a booth and activities at several public events. We present visitor survey results from a recent exhibition at Dragon*Con, a sci-fi/fantasy convention with over 50,000 attendees. We discuss future plans for the project, including the release of several mobile apps to be previewed here.

448.10 – iMap: A stable layout for navigating the Astronomy Picture of the Day image collection with embedded search

Robert J. Nemiroff[1], Chaoli Wang[1], John P. Reese[1], Huan Zhang[1], Jun Tao[1], Jerry Bonnell[2, 3]
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Effective techniques for organizing and visualizing large image collections are in growing demand as visual search becomes increasingly popular. Targeting an online astronomy archive -- the Astronomy Picture of the Day (APOD) archive with thousands of images -- we present a practical organizational approach for image search and clustering based on a measure of image similarity that leverages both visual and textual information. To lay out images, we introduce iMap, a treemap-based representation for visualizing and navigating image search and clustering results. We show the effectiveness of our approach by demonstrating experimental results from a comparative user study. The results indicate that iMap makes relevant images in APOD easier to find, in particular for educators seeking astronomy images to augment topical or educational classroom presentations.

448.11 – A Comparison of Astronomy/Science Attitudes Among Students and Secondary Teachers

Anna Kareva[1], Scott Miller[1], Andrea Foster[1], C. R. James[1]
1. Sam Houston State University, Huntsville, TX, United States.

The Astronomy Summer School of East Texas was designed to address the needs of rural schools in the Walker County region of East Texas. This region is populated by poorer schools with fewer science resources and underperforming students on standardized tests, resulting in many of the school districts being rated as "academically unacceptable". The goal of the workshop was to provide a suite of active learning modules to regional 6 – 12 grade teachers, which they can then use in their classrooms to actively engage their students in the use of real science data. As part of the workshop, we administered Zeilik's pre/post attitude survey towards astronomy/science to assess whether the participant's attitudes changed over the course of the two-week workshop. While we found no statistically significant shift in attitudes, we were surprised at some of the attitudes that secondary science teachers held. We will summarize their attitudes and compare them with attitude data gathered from their students, along with those of college students enrolled in introductory astronomy courses at Sam Houston State University. With this data, we will present the differences in attitudes with age between middle school, high school and college students, along with difference in attitudes between teachers and students. This project is supported by the NASA Science Mission Directorate Education and Public Outreach for Earth and Space Science (EPOESS), which is part of the Research Opportunities in Space and Earth Sciences (ROSES), Grant Number NNX12AH11G.

448.12 – Gains in Astronomy Content Knowledge an ASSET to East Texas Secondary Teachers

Cale Lewis[1], Scott Miller[1], Andrea Foster[1], C. R. James[1]
1. Sam Houston State University, Huntsville, TX, United States.

Recent analysis of SAT performance nationwide has demonstrated that Texas ranks 46th out of the 50 states in math SAT scores, and that statewide, only 42% of all 11th graders meet the minimum recommended level of standards in standardized science aptitude. Walker County, within the Piney Woods region of East Texas, is populated by rural, poorer school districts with a large percentage of minority students. Due in part to a lack of resources not only for the students, but also for the educators, students in this region suffer poor science education skills. In attempt to build these skills, we designed a NASA funded workshop, Astronomy Summer School of East Texas (ASSET). ASSET aimed to: (1) develop a suite of inquiry-based activities that guide rural East-Texas high school teachers and pre-service teachers to a better understanding of the tools and methods of astronomy and, (2) train current and future educators on the methods of science. ASSET focused on inquiry-based lessons and hands-on activities that engaged the teacher participants, supplemented by content lectures. We gauged the effectiveness of each lesson by administering a pre/post content survey, and calculated the normalized gain, $<g>$, for each question. While many questions imply mid- to high-normalized gain for each concept, we find the highest gains for questions directly related to activities that strongly engaged the participants. We also found through an evaluation survey a discrepancy between the concepts where participants rated themselves as improving in understanding versus the concepts where high levels of improvement actually occurred. This project is supported by the NASA Science Mission Directorate Education and Public Outreach for Earth and Space Science (EPOESS), which is part of the Research Opportunities in Space and Earth Sciences (ROSES), Grant Number NNX12AH11G.

449 – Professional Development Workshops and Programs for Teachers

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

449.01 – From the Universe to the Classroom : A Professional Development Program for Hubble and Webb

Bonnie Eisenhamer[1], Frank Summers[1], Dan McCallister[1], Holly Ryer[1], Linda Knisely[1]
1. STScI, Baltimore, MD, United States.

The education team at the Space Telescope Science Institute (STScI) designs professional development workshops that support the needs of the education community. The purpose of these workshops is to share the latest information about the Hubble and James Webb space telescopes, current NASA science, and curriculum support tools with the education community. The workshops also address STEM topics and the latest educational research, while emphasizing real-world connections. Over the years, our professional development program has been pivotal to disseminating resources, providing educators with the necessary background to use these resources, and helping us better understand community needs. Educators and scientists are both critical to the implementation of quality professional development due to their unique areas of expertise. As a result, our professional development program is founded on the experience of educators who work in partnership with scientists and other content experts. These teams develop workshops that enhance educators' content and pedagogical knowledge. This poster will highlight examples of how scientists and educators have worked together to develop workshop materials and content.

449.02 – Teacher Professional Development in Laredo, TX

Keely D. Finkelstein[1], Lucas M. Macri[2], Mary Kay Hemenway[1], Marc Wetzel[3], Sandra Preston[1], Magdalena Rood[4]
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In the fall of 2012, McDonald Observatory, Texas A&M University, and Texas A&M International University conducted a series of workshops on astronomy content for 5th – 8th grade teachers in Laredo, Texas. Three one-day workshops were held at the Lamar Bruni Vergara Planetarium of Texas A&M International University, using a mix of in-person and distance learning technology. Texas A&M professor Lucas Macri gave public talks in English and Spanish, and a lunch-time presentation to the teachers. A series of evaluation tools were used to assess the success of the workshops. A Nominal Group Technique (NGT) discussion was used, through which groups developed consensus answers about their learning, expectations for classroom use, and satisfaction with the workshop. The Astronomy/Space Science Test (MOSART Grades 5-8) was also issued as a pre- and post-test to assess gains in knowledge. Teacher consensus was that the materials and activities of the workshop had been helpful for learning and that they expected to use many of them in their classrooms. However, the evaluation also showed that teachers would have preferred the Observatory educator be physically present for all workshops. Past video-conferencing workshops, where local facilitators first participated in workshops at the Observatory, showed better feedback and results concerning this point. Comparing those results to the present case, we conclude that more clearly defined roles and better training for the science specialists and local facilitators would improve the video conference experience for the teachers. Comparison of pre- and post-test results showed improved teacher knowledge. An additional benefit of this project was the further development of partnerships between McDonald Observatory and Texas A&M International University, which has resulted in further education projects, including a video-conference presentation series to eight-grade students and their families. This secondary project focused on motivating and increasing underserved students from the Laredo area in STEM fields, and featured lectures from University of Texas / McDonald Observatory astronomers.

449.03 – Network for Astronomy School Education

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The Network for Astronomy School Education Project (NASE) was developed in response to the IAU's most recent 10 Years Strategic Plan to increase the efforts of the IAU in schools. NASE's mission is to stimulate teaching astronomy in schools, through professional development of primary and secondary school science teachers in developing and emerging countries. NASE's organizational principle is to build capacity by providing courses for three years in cooperation with a Local Organizing Committee (Local NASE Group). The Local NASE Group consists of 6-8 local university professors and education professional who will promote astronomy activities and organize future courses in subsequent years in their region of their

country. NASE philosophy is to introduce low-tech astronomy, and has thus developed an a suite of activities that can be carried out with inexpensive, quotidian materials. Supporting these activities is a text for teachers, plus a complete set of instructional materials for each topic. These materials are available in English and Spanish, with future editions available in Chinese and Portuguese. We describe and discuss NASE activities in Central and South America from 2009 to the present.

449.04 – Collaboration between research scientists and educators to prepare new Earth Science teachers

Ashley Pagnotta[1], Jana Grcevich[1], Michael Shara[1], Mordecai-Mark Mac Low[1], Kennet Flores[1], Patricia A. Nadeau[1], Jocelyn Sessa[1], Gokce Ustunisik[1], Nasser Zirakparvar[1], Denton Ebel[1], George Harlow[1], James D. Webster[1], Rosamond Kinzler[1], Maritza B. MacDonald[1], Julie Contino[1], Natasha Cooke-Nieves[1], Elaine Howes[1], Marion Zachowski[1]
1. American Museum of Natural History, New York, NY, United States.

The Master of Arts in Teaching (MAT) Program at the American Museum of Natural History is a first-of-its-kind program designed to prepare participants to be world-class Earth Science teachers. The lack of Earth Science teachers in New York State has resulted in fewer students taking the statewide Earth Science Regents Exam, which negatively affects graduation rates and reduces the number of students who pursue related college degrees. The MAT program was designed to address this problem, and is the result of a collaboration between research scientists and educators at the Museum, with faculty comprised of curators and postdoctoral researchers from the Departments of Astrophysics, Earth and Planetary Sciences, and the Division of Paleontology, as well as doctoral-level Education faculty. The full-time, 15-month program combines courses and field work in astrophysics, geology, earth science, and paleontology at the Museum with pedagogical coursework and a teaching residency in local urban classrooms. The MAT program targets high-needs schools with diverse student populations and therefore has the potential to stimulate interest and achievement in a variety of STEM fields among thousands of students from traditionally underrepresented backgrounds. The first cohort of candidates entered the MAT program in June of 2012 and finished in August of 2013. Nineteen new Regents-qualified Earth Science teachers are now in full-time teaching positions at high-needs schools in New York State. We report on the experience of the first cohort as well as the continuation of the program for current and future cohorts of teacher candidates.

449.05 – The Arizona Galileoscope Project: A 5th Grade Rural Education Program

Robert T. Sparks[1], Stephen M. Pompea[1], Chuck Dugan[1], Constance E. Walker[1]
1. NOAO, Tucson, AZ, United States.

The Galileoscope is a low cost, high quality telescope kit developed for the International Year of Astronomy (IYA). Over 200,000 Galileoscopes have been sold and used by the public and education programs around the world. The National Optical Astronomy Observatory has been a leader in Galieoscope education programs. In 2009 we started the Arizona Galileoscope Star Party Program. We have partnered with rural school districts around the state including Flagstaff, Safford, Yuma, Globe and Payson to bring Galilesocope educational program to the students and teachers. The program begins with a professional development workshop where teachers learn about the optics of telescopes and how to assemble the Galileoscope and use it on a tripod. The teachers receive a Teaching With Telescopes (TWT) kit that contains a variety of lenses, lasers and lights to do all the activities in the workshop and a classroom supply of Galileoscopes and tripods to take back to their classroom. Their students learn about telescope optics and how to use a Galileoscope. Several weeks after the professional development workshop, a district wide star party is held for the parents, teachers and students. In the coming years, we are expanding the program in cooperation with Science Foundation Arizona. We are currently in the process of recruiting new cities to join the program in addition to supporting our previous communities. We will describe our past efforts, the evaluation of the program and our future expansion.

450 – Education and Public Outreach Resources

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

450.01 – Using Kepler Light Curves for Astronomy Education and Public Outreach

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1. South Carolina State Univ., Orangeburg, SC, United States. 2. The Lawrence Hall of Science, Berkeley, CA, United States.

We will present our efforts related to Education and Public Outreach activities using Kepler Light Curves. We are currently developing interactive web based activities to introduce the public to the general topic of Stellar Variability and Intrinsic Variable Stars in particular using the high quality light curves of over a dozen Kepler targets. Along with the public website, we are exploring areas to develop teacher guides to use Kepler Light Curves in the middle and high school classrooms. These efforts are supported through a NASA EPSCoR grant "South Carolina Joint Venture Program" via a subaward to SC State University.

450.02 – On-line Eclipse Resources from the U.S. Naval Observatory: Planning Ahead for April 2024

Amy C. Fredericks[1], Jennifer L. Bartlett[1], Steve Bell[2], James C. Stapleton[3, 1]
1. US Naval Obs., Washington, DC, United States. 2. Her Majesty's Nautical Almanac Office, Taunton, United Kingdom. 3. SEAP, Washington, DC, United States.

On 8 April 2024, "…night from mid-day…" (Archilochus, 648 BCE) will appear to fortunate observers along a narrow band, approximately 115 mi (185 km) wide, that crosses fifteen states from Texas to Maine. In response to growing interest in the two total solar eclipses that will sweep the continental United States in the next 11 years, the U.S. Naval Observatory has developed an on-line resource center with direct links to 2024-specific services: the 2024 April 8 Total Solar Eclipse page (http://aa.usno.navy.mil/data/docs/Eclipse2024.php). The Solar Eclipse Computer (http://aa.usno.navy.mil/data/docs/SolarEclipses.php) calculates tables of local circumstances for events visible throughout the world. A similar service is available for lunar eclipses, Lunar Eclipse Computer (http://aa.usno.navy.mil/data/docs/LunarEclipse.php). The USNO Eclipse Portal (http://astro.ukho.gov.uk/eclbin/query_usno.cgi) provides diagrams and animations showing the global circumstances for events visible throughout the world and local circumstances for events visible at selected locations. The Web site, which includes both solar and lunar eclipses, is a joint effort with Her Majesty's Nautical Almanac Office. The Eclipses of the Sun and Moon page (http://aa.usno.navy.mil/data/docs/UpcomingEclipses.php) links to electronic copies of the visibility maps from The Astronomical Almanac. The Eclipse Reference List (http://aa.usno.navy.mil/faq/docs/eclipse_ref.php) is a representative survey of the available literature for those interested in delving into these phenomena, either technically or historically. As exciting as the 2024 total solar eclipse, another spectacular event will precede it; a total solar eclipse will cross a different swath of the continent on August 21, 2017. The U.S. Naval Observatory has a resource center for that event as well (http://aa.usno.navy.mil/data/docs/Eclipse2017.php) . If your plans for 2024 are not yet made, visit the 2024 April 8 Total Solar Eclipse page to prepare for up to 4 minutes 31 seconds of "unexampled beauty, grandeur, and impressiveness" (Newcomb 1890) and of darkness.

450.03 – Educating the Public about Meteorites and Impacts through Virtual Field Trips and Classroom Experience Boxes

Teresa Ashcraft[1], Rebekah Hines[1], Michelle Minitti[2], Wendy Taylor[3, 4], Melissa A. Morris[1], Meenakshi Wadhwa[1]
1. Center for Meteorite Studies, School of Earth & Space Exploration, Arizona State University, Tempe, AZ, United States. 2. Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, United States. 3. University of Cape Town, Cape Town, South Africa. 4. School of Earth & Space Exploration, Arizona State University, Tempe, AZ, United States.

With specimens representing over 2,000 individual meteorites, the Center for Meteorite Studies (CMS) at Arizona State University (ASU) is home to the world's largest university-based meteorite collection. As part of our mission to provide educational opportunities that expand awareness and understanding of the science of meteoritics, CMS continues to develop new ways to engage the public in meteorite and space science, including the opening of a new Meteorite Gallery, and expansion of online resources through upgrades to the CMS website, meteorites.asu.edu. In 2008, CMS was the recipient of a philanthropic grant to improve online education tools and develop loanable modules for educators. These modules focus on the origin of meteorites, and contain actual meteorite specimens, media resources, a user guide, and lesson plans, as well as a series of engaging activities that utilize hands-on materials geared to help students develop logical thinking, analytical skills, and proficiency in STEM disciplines. In 2010, in partnership with the ASU NASA Astrobiology Institute team, CMS obtained a NASA EPOESS grant to develop Virtual Field Trips (VFTs) complemented by loanable "Experience Boxes" containing lesson plans, media, and hands-on objects related to the VFT sites. One VFT-Box pair focuses on the record of the

oldest multicellular organisms on Earth. The second VFT-Box pair focuses on the Upheaval Dome (UD) structure, a meteorite impact crater in Utah's Canyonlands National Park. UD is widely accepted as the deeply eroded remnant of a ~5 kilometer impact crater (e.g. Kriens et al., 1999). The alternate hypothesis that the Dome was formed by the upwelling of salt from a deposit underlying the region (e.g. Jackson et al., 1998) makes UD an ideal site to learn not only about specific scientific principles present in the Next Generation Science Standards, but also the process of scientific inquiry. The VFTs are located on an interactive website dedicated to VFTs, vft.asu.edu. Starting in 2014, the accompanying Boxes will be housed with CMS and other educational partners for educators to borrow free of charge.

450.04 – Make Movies out of Your Dynamical Simulations with OGRE!

Daniel Tamayo[1], Robert W. Douglas[2], Heming W. Ge[1], Joseph A. Burns[1]
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We have developed OGRE, the Orbital GRaphics Environment, an open-source project comprising a graphical user interface that allows the user to view the output from several dynamical integrators (e.g., SWIFT) that are commonly used for academic work. One can interactively vary the display speed, rotate the view and zoom the camera. This makes OGRE a great tool for students or the general public to explore accurate orbital histories that may display interesting dynamical features, e.g. the destabilization of Solar System orbits under the Nice model, or interacting pairs of exoplanets. Furthermore, OGRE allows the user to choreograph sequences of transformations as the simulation is played to generate movies for use in public talks or professional presentations. The graphical user interface is coded using Qt to ensure portability across different operating systems. OGRE will run on Linux and Mac OS X. The program is available as a self-contained executable, or as source code that the user can compile. We are continually updating the code, and hope that people who find it useful will contribute to the development of new features.

450.05 – The Fulldome Curriculum for the Spitz SciDome Digital Planetarium: Volume 2

David H. Bradstreet[1], Steven J. Sanders[1], Scott Huggins[2]
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The Spitz Fulldome Curriculum (FDC) for the SciDome digital planetarium ushered in a new and innovative way to present astronomical pedagogy via its use of the unique teaching attributes of the digital planetarium. In the case of the FDC, which uses the ubiquitous Starry Night planetarium software as its driving engine, these engaging and novel teaching techniques have also been made usable to desktop computers and flat-screen video projectors for classroom use. Volume 2 of the FDC introduces exciting new classes and mini-lessons to further enlighten and invigorate students as they struggle with often difficult three dimensional astronomical concepts. Additionally, other topics with related astronomical ties have been created to integrate history into planetarium presentations. One of the strongest advantages of the SciDome is its use of Starry Night as its astronomical engine. With it students can create their own astronomical configurations in the computer lab or at home, using the PC or Mac version. They can then simply load their creations onto the SciDome planetarium system and display them for their classmates on the dome. This poster will discuss and illustrate some of the new content that has been developed for Volume 2. Topics covered in Volume 2 include eclipses, plotting planet locations on a curtate orbit chart by observing their positions in the sky, time and timekeeping (including sidereal day, hour angles, sidereal time, LAST, LMST, time zones and the International Date Line), teaching to the Boy Scout Merit Badge requirements, plotting scale analemmas on the surface of planets and interpreting them, precession, astronomical events in revolutionary Boston, the Lincoln Almanac Trial, eclipsing binaries, lunar librations, a trip through the universe, watching the speed of light move in real time, stellar sizes and the Milky Way.

450.06 – Locating the Great Red Spot: Yesterday, Today, and Tomorrow

Michael V. Lesniak[1], James C. Stapleton[1,2]
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The Great Red Spot, a persistent storm in Jupiter's atmosphere, is the most prominent feature of that planet's disk as viewed from Earth. Combined with the fact that Jupiter is a gas giant planet and has no visible surface with discernible landmarks, this means that following the passage of the Great Red Spot is the primary method of observing the planet's rotation. Therefore, it is paramount for any program which generates synthetic images of the planet to accurately place the feature. The U.S. Naval Observatory's "Apparent Disk of a Solar System Object" online web service (http://aa.usno.navy.mil/data/docs/diskmap.php) is such a program. The Great Red Spot's planetary latitude is locked between two of Jupiter's striated atmospheric layers at 22 °S. However, its planetary longitude is not constant; over time it migrates east and west along the atmospheric layer boundary it is trapped within. Observing and recording its longitude is made difficult because Jupiter's atmosphere is subject to differential rotation and the Great Red Spot slowly migrates with respect to the surrounding atmospheric layers. Furthermore, the Great Red Spot does not move at a uniform rate. Currently its relative motion is approximately 0°.051 per day. Since its first recorded observation in 1831, the Great Red Spot has made almost three complete laps around the planet at the 22nd parallel. "Apparent Disk of a Solar System Object" operates over any requested

date between 1700 and 2100 A.D. Therefore, our treatment of the Great Red Spot needs to take into account both historical positions and future predicted motion. Based on researching past observations of the spot's position on the disk, we find that its behavior prior to 2009 is best represented by a 10-part piecewise function. Each component of the piecewise function is a 2nd order polynomial. Observations from 2009-present are better fit with a linear function; this function is used for future years by extrapolation. Using these fits to observations requires occasional maintenance to the predictive function because the Great Red Spot's rate of longitude motion is non-uniform.

450.07 – Exploring the Early Universe on Mobile Devices

Dale Kocevski[1], Elizabeth J. McGrath[2]
1. University of Kentucky, Lexington, KY, United States. 2. Colby College, Waterville, ME, United States.
Contributing teams: The CANDELS collaboration

The widespread adoption of smart phones and tablet computers has the potential to revolutionize the way in which educational material is shared with the general public. As part of the outreach effort for the CANDELS survey, we have developed a free interactive astronomy education application named Hubble Universe for iPad and iPhone devices. The application focuses on extragalactic science topics related to the CANDELS legacy survey, which is documenting galaxy evolution in the early universe. I will provide an overview of the application, which contains a wide range of interactive content, including 3D models of astrophysical phenomenon, informative diagrams and computer simulations. I will discuss how the application can be used to enhance classroom learning both by providing a database of interactive media and by encouraging students to explore astronomical topics away from traditional settings like the classroom or the desktop computer.

450.08 – How did the Supreme Court ruling on DOMA affect astronomers?

Jane R. Rigby[1]
1. NASA Goddard, Greenbelt, MD, United States.
Contributing teams: The AAS Working Group on LGBTIQ Equality

In June 2013, the United States Supreme Court ruled that Section 3 of the Defense of Marriage Act (DOMA) was unconstitutional. Section 3 had barred the federal government from recognizing same-sex marriages. The decision in *United States v. Windsor*, made headlines around the world, and particularly affected astronomers, since astronomers in the US are more likely than the general population to be foreign nationals, to have a foreign-born spouse, or to work for the federal government. In this poster, we highlight some of the real-world ways that the *Windsor* case has affected US astronomers and our profession. Bi-national couples can now apply for green cards granting permanent residency. Scientists who work for the federal government, including NASA and the NSF, can now obtain health insurance for a same-sex spouse. From taxes to death benefits, health insurance to daycare, immigration to ethics laws, the end of S3 of DOMA has had profoundly improved the lives of US scientists who are lesbian, gay, bisexual, or transgender (LGBT). Here we, highlight several real-world examples of how DOMA's demise has improved the lives and careers of US astronomer.

450.09 – Developing Spatial Reasoning Through 3D Representations of the Universe

Frank Summers[1], Bonnie Eisenhamer[1], Dan McCallister[1]
1. STScI, Baltimore, MD, United States.

Mental models of astronomical objects are often greatly hampered by the flat two-dimensional representation of pictures from telescopes. Lacking experience with the true structures in much of the imagery, there is little basis for anything but the default interpretation of a picture postcard. Using astronomical data and scientific visualizations, our team has worked in both formal and informal educational settings to explore and foster development of spatial reasoning while forming more accurate and richer mental models. Employing inquiry-based methods, participants examine, imagine, predict, and confront the 3D interpretation of well-known 2D imagery using data from NASA, the Hubble Space Telescope, and other scientific sources. Examples include star positions and constellations, morphologies of both normal and interacting galaxies, shapes of planetary nebulae, and three dimensional structures in star forming regions. Of particular appeal to educators is the activity's cross-disciplinary nature which includes science, math, and artistic reasoning while addressing common cosmic misconceptions.

451 – Astronomy 101: Courses and Resources
Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

451.01 – A Coherent Content Storyline Approach for Introductory Astronomy

Christopher Palma[1], Alice Flarend[2, 1], Scott McDonald[1], Julia M. Kregenow[1]
1. Penn State Univ., University Park, PA, United States. 2. Bellwood-Antis High School, Bellwood, PA, United States.

The Earth and Space Science Partnership (ESSP) is a collaboration among Penn State scientists, science educators and seven school districts across Pennsylvania. Part of the multi-faceted ESSP effort includes revising the curriculum of university science classes known to be taken by large numbers of elementary pre-service teachers. By adopting research-based pedagogical approaches in our courses, we hope to expose these pre-service teachers to excellent examples of science teaching. In this presentation, we will discuss changes made in a pilot study to one section of our introductory astronomy survey course. There have been many articles published in the Astronomy Education Review and elsewhere that detail research-based pedagogical practices for introductory astronomy courses. Many of those practices (such as from the Center for Astronomy Education) have been incorporated into introductory astronomy courses at Penn State. However, our work with middle-grades teachers in the ESSP project is based on two key practices: a Claims, Evidence, and Reasoning (CER) framework (McNeill & Krajcik 2012) and a coherent science content storyline (Roth,et. al., 2011). As a first step in modeling these practices in our University courses, we reorganized our Astro course using a content storyline approach. We plan to incorporate CER activities into the course next year that advance the storyline described. In this poster, we present the storyline developed by our team, which we believe was successful in its pilot, and was built around a conceptually coherent presentation of the diverse set of phenomena typical of an introductory astronomy course. We adopted as our main learning goal a statement based on the cosmological principle that the physical laws throughout the Universe are identical everywhere. In addition, we organized the class schedule to connect the work done in each class to this storyline. We suggest that a coherent content storyline is a useful tool for others who teach broad survey astronomy courses similar to ours at Penn State. We gratefully acknowledge support from the NSF MSP program award DUE#0962792.

451.02 – Student Mastery of the Sun-Earth-Moon System in a Flipped Classroom of Pre-service Elementary Education Students

Kristine Larsen[1]
1. Central Connecticut State University, New Britain, CT, United States.

One of the current trends in pedagogy at all levels(K-college) is the so-called 'flipped classroom', in which students prepare for a class meeting through self-study of the material. It is based on a rejection of the classic model of the faculty member as the 'sage on the stage'; instead, responsibility for learning shifts to the individual student. The faculty member takes on the role of learning facilitator or mentor, and focuses the students' learning by crafting and administering timely formative assessments (in multiple formats and applied multiple times) that aid both students and the faculty member in tracking the students' mastery of the learning outcomes. In a flipped, freshman-only, section of SCI 111 Elementary Earth-Physical Sciences (a required introductory science course for pre-service elementary school teachers) the students learned through a combination of individual and group hands-on in-class activities, technology (including PowerPoint presentations and short videos viewed prior to attending class), in-class worksheets, and in-class discussions. Students self-differentiated in how they interacted with the available teaching materials, deciding which activities to spend the most time on based on their individual needs (based on an online quiz taken the night before the class period, and their personal self-confidence with the material). Available in-class activities and worksheets were developed by the faculty member based on student scores on the online quiz as well as personal messages submitted through the course management system the night before the class meeting. While this placed a significant burden on the faculty member in terms of course preparation, it allowed for just-in-time teaching to take place. This poster describes the results of student mastery of content centered on the sun-earth-moon system (specifically seasons, moon phases, and eclipses) as compared to traditional classroom sections.

451.03 – The New Astro 001 Video Game Course at Penn State

Jane C. Charlton[1], Andrew Mshar[1], Nahks Tr'Ehnl[1]
1. Penn State Univ., University Park, PA, United States.

The week after this meeting will see the premiere of the Astro 001 Video Game course at Penn State. Non-science majors at Penn State will learn basic astronomy through an immersive 3D video game written in the Unity game engine. Students join the first study abroad on Mars program and wander the landscape of Mars, living in the first Mars colony. In a virtual reality lab they will adventure through the Solar System, explore other stars and their planetary systems, zoom to other galaxies, and venture back into time. Sub-games will teach complex concepts like phases of the moon, spectroscopy, galaxy classification, nuclear reactions, and more. The course relies on some of the best external websites for some activities while others are of our own design, but all fit in with a single story. Students have the opportunity to be a part of the story, frequently answering questions as they progress. This new course follows on a successful story-based online course at Penn State that has been taken by over 12,000 students. In that course, test scores were significantly improved over those in the

lecture section by the same instructor, and student satisfaction was high. We believe that the video game version will be even more motivating and will allow for students to be immersed in more challenging and rewarding explorations.

451.04 – Astro101 at Tohono O'odham Community College

Catharine D. Garmany[1], Colette Salyk[1]
1. NOAO, Tucson, AZ, United States.

Tohono O'odham Community College is a relatively new tribal college, chartered in 1998, and located at the foot of loligam Doag , the mountain where Kitt Peak National Observatory is located. Although Garmany taught astronomy there several times in the past, the course had not been offered for a while. After discussions with the college, we agreed to remedy this, and so this fall we taught Astro 101 to an enthusiastic class of 12 students. Since the class is offered as a lab class, we naturally made use of the National Observatory: our students had multiple opportunities to visit Kitt Peak at night. We describe our experience, lessons learned, and our ideas for future classes and collaboration with the college.

451.05 – Crank Astronomy as a Teaching Tool. II.

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Many astronomers – and indeed, scientists in general – have dealt with them: You receive one or more emails from intense individuals who insist that your interpretation of any data is wrong and THEIR idea is Truth (with a capitol "T"). The person contacting you might have some scientific background, or none at all. You might respond to the individual, trying to be helpful, perhaps pointing out some misinterpretation they have of your results, or a fatal flaw their idea. They respond with accusations of ignorance, incompetence and conspiracies, and it goes rapidly downhill from there. While most scientists consider these individuals – some of whom are part of more organized groups with various non-scientific agendas – as a nuisance, it might be better to regard them as an opportunity to improve classroom teaching. A surprising number of the claims from these individuals can be addressed at the level of introductory physics or other science classes. They provide simple examples of hypotheses that do not work making them valuable for teaching science and critical thinking. These skills are important for any member of the scientifically literate public and are imperative for any scientist. We present some crank astronomy claims with a focus on heliophysics which are suitable for actual analysis by students with undergraduate-level physics background. The analyses may also be suitable for high school physics classes. We also encourage educators interested in using examples of where people go wrong in their thinking to use these as teachable examples. Some lessons, writing assignments, or extra credit can be assigned to students to require them to use both critical thinking and the information learned in class to counter these kinds of claims. In doing so, one not only encourages the development of a student's critical thinking that will serve them in any field, but the student is also better prepared when they will face similar types of claims in the future.

451.06 – The Astronomy Workshop Extragalactic: Web Tools for Use by Students

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The Astronomy Workshop Extragalactic (http://carma.astro.umd.edu/AWE) is a collection of interactive web tools that were developed for use in undergraduate and high school classes and by the general public. The focus of the tools is on concepts encountered in extragalactic astronomy, which are typically quite difficult for students to understand. Current tools explore Olbers' Paradox; the appearance of galaxies in different wavelengths of light; the Doppler Effect; cosmological redshift; gravitational lensing; Hubble's Law; cosmological parameters; and measuring masses of black holes by observing stellar orbits. The tools have been developed by undergraduate students under our supervision and we are planning to continue to add more tools. This project was inspired by the Astronomy Workshop (http://janus.astro.umd.edu) by Doug Hamilton which has web tools exploring more general astronomical concepts. We would like to thank the NSF for support through the CAREER grant NSF-AST0955836, and the Research Corporation for Science Advancement for a Cottrell Scholar award.

451.07 – Building a Comprehensive Online Homework System for Astro 101 within Sapling Learning

Andrea Urban[1]
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What does an effective homework system for Astro 101 look like? We discuss the method of creating a library of questions for Astro 101 as well as the philosophy behind the types of homework questions (and feedback) that are written within the Sapling Learning homework system. We also discuss which topics may require deeper investigations and how they can be addressed using interactive simulations.

451.08 – A FERPA-compliant Workflow for Efficiently Returning Classwork to Students in Large Lecture Classes

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In-class activities are invaluable tools to both stimulate student learning in large lecture-classes, and also to provide the instructor with feedback on the level of student comprehension of material. However, it is not trivial to return (1-few)$\times 10^2$ graded worksheets to students in a way that both 1. prevents others from viewing the information and grade of the student, and, 2. does not add significant logistical overhead on the part of the instructor. Furthermore, when classwork is *not* returned to the student, its absence as a study resource is then among the most common complaints from students. I will briefly present a workflow that meets both the above goals: 1. at no point is the student's information or grade released to others, and 2. the overhead incurred in the returning of the work is short compared to the time taken for the original grading. I will also introduce the software tool I use to greatly streamline this workflow, and which will be made available to the community.

451.09 – 101 Astro Honors Laboratory Exercises using the Hubble Legacy Archive, the Digitized Sky Survey on MAST, and Stellar Spectral Catalogs.

Jason S. Kendall[1]

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Introductory lab exercises and documents are presented that can be used with Honors-student introductory astronomy students in a dedicated laboratory section. The three lab exercises involve using the Hubble Legacy Archive to create a color-magnitude diagram, use of stellar spectra standards catalog to learn spectral classification, and the Digitized Sky Survey on MAST to present the students with a challenging morphological exercise. The labs contrast with some of the standard physics-based labs, and focusing on encountering data in an astronomical context. Appropriate for a lab section of between 15 and 25 students, each exercise lasts approximately two hours, and are designed to be done in teams. The first two labs have a strong advantage that the primary answers cannot be obtained with ease from various internet search engines. The DSS/MAST exercises deliberately exploits the ubiquity of portable computers in the possession of the students in classes, and forces them to do extensive image and data comparison and interpretation. The labs have all been used in multiple sections, as well as workshops with amateur astronomers, with the greatest success in the stellar spectra lab.

452 – Increasing the Accessibility of Astronomy Poster Session
Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

452.01 – The SMARTS Observatory: Rich Science Accessible for Everyone

Imran Hasan[1,2], Victoria Misenti[1,2], Todd J. Henry[3,1]
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The SMARTS observatory announces opportunities for new members to use the SMARTS telescopes--the 1.5m, 1.3m, and 0.9m in at CTIO in Chile-- to carry out their science programs. We have entered a new era for the consortium, SMARTS3, with an agreement to continue operations through September 2016. In light of this, we are accepting both individual and institutional members on a first-come, first-served basis. The advantages of SMARTS include long-term science, queue scheduling with flexibility for targets of opportunity, daily data reduction and distribution, and assistance from the dedicated SMARTS and CTIO teams. SMARTS Observatory has been producing excellent science for over 10 years. With 23 members from 11 institutions, SMARTS provides observational data for a diverse number of projects. Our productivity and capability is evidenced by many publications in various fields, among them comprehensive novae observations, long-term AGN monitoring, and discoveries of planets via micro-lensing. In this poster, we show scientific highlights from SMARTS users as well as statistics on its productivity. We provide details about how the SMARTS Consortium currently functions, what it costs to participate, and how to become a member.

452.02 – AstroDance: Teaching Astrophysics Through Dance?

Jacob Noel-Storr[1], Manuela Campanelli[1], Joseph Bochner[1], Thomas Warfield[1], Hans-Pieter Bischof[1], Yosef Zlochower[1], Jason Nordhaus[1], Greyson Watkins[1]
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Contributing teams: NSF CRPA AstroDance Team

Through a collaboration involving scientists, artists and educators, members of the Center for Computational Relativity and Gravitation and the National Technical Institute for the Deaf at the Rochester Institute of Technology we developed a unique project for Communicating Research to Public Audiences. The project used dance and multi-media theater techniques to expose a broad audience, about half of which is comprised of deaf and hard-of-hearing individuals, to an aesthetic, educational performance representing the concepts of gravitational physics in astrophysical settings. Since deaf and hard-of-hearing people rely heavily on visual communication for learning and gaining access to information, dance and multi-media theater provide a kinesthetic and visual experience that is fully accessible to them, as well as hearing audience members, and help facilitate their learning and development of non-linguistic representations of concepts. Here we present the results of our research into the learning outcomes for the diverse audiences of this project in terms of both knowledge and attitudes towards science.

453 – Spiral Galaxies Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

453.01 – A Two-Parameter Model for the Infrared/Submillimeter/Radio Spectral Energy Distributions of Galaxies and AGN

Daniel A. Dale[1], George Helou[2], Georgios Magdis[3, 4], Dimitra Rigopoulou[3]
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Contributing teams: 5MUSES,HerMES

A two-parameter semi-empirical model is presented for the spectral energy distributions of galaxies with contributions to their infrared-submillimeter-radio emission from both star formation and accretion disk-powered activity. This model builds upon a previous one-parameter family of models for star-forming galaxies. SF/AGN diagnostics based on PAH equivalent widths and broadband infrared/submillimeter colors are presented, and example AGN fractional contributions are estimated from model fits to sources at redshifts $0 < z < 2$.

453.02 – Constraining dark matter halo profiles using spiral arm morphologies: Dark and stellar mass concentrations for 13 nearby face-on galaxies

Marc Seigar[1], Benjamin L. Davis[2], Joel C. Berrier[2], Daniel Kennefick[2], Julia D. Kennefick[2]
1. University of Arkansas at Little Rock, Little Rock, AR, United States. 2. University of Arkansas at Fayetteville, Fayetteville, AR, United States.

We investigate the use of spiral arm morphology as a probe of disk galaxy mass profiles. We confirm our previous result that spiral arm pitch angles (P) are well correlated with rotation curve shear (S) in disk galaxies. We use this correlation to argue that imaging data alone can provide a powerful probe of galactic mass distributions out to large lookback times. We then use a sample of 13 galaxies with Spitzer 3.6-μm imaging data and observed Hα rotation curves to demonstrate how and inferred shear coupled with a bulge-disk decomposition model and a Tully-Fisher-derived velocity normalization can be used to place constraints on a galaxy's baryon fraction and dark matter halo density profile. Finally, we show that their appears to be a trend between spiral arm pitch angle and halo concentration (albeit a weak correlation). We discuss implications for the suggested link between supermassive black hole (SMBH) mass and dark halo concentration using pitch angle as a proxy for SMBH mass.

453.03 – A Stacking Analysis of the Free-Free Opacity of Spiral Galaxy Disks

Jeroen M. Stil[1], Tristan Klassen[1], Benjamin W. Keller[1, 2]
1. Univ. of Calgary, Calgary, AB, Canada. 2. McMaster University, Hamilton, ON, Canada.

The relative distribution of synchrotron emission and ionized gas in spiral galaxies is an important factor for modeling diffuse polarized emission of galaxies. HII regions in particular have been shown to completely depolarize background diffuse synchrotron emission at 1.4 GHz. Free-free absorption of low-frequency radio emission provides a global measure of the covering factor of synchrotron emission by relatively dense plasma, but evidence for inclination-dependent free-free absorption in spiral galaxies remains inconclusive. We have performed a stacking analysis of radio emission of PGC (Principle Galaxies Catalog) spiral galaxies, using the NRAO VLA Sky Survey (NVSS; at 1400 MHz), the Westerbork Northern Sky Survey (WENSS at 325 MHz) and the VLA Low-frequency Sky Survey (VLSS at 74 MHz). Accounting for the finite extent of the target galaxies in the synthesized beam of the surveys, we find spectral indices $\alpha^{1400}_{325} = 0.86 \pm 0.03$ and $\alpha^{325}_{74} = 0.60 \pm 0.10$. Surprisingly, our analysis shows that for galaxies selected by angular size of the optical major axis, the median flux density in *all three* surveys decreases with inclination, up to almost 50% for the most inclined galaxies. The same result was obtained for stacked aperture-integrated flux density, the 25% and 75% percentiles of the stack, and for a new statistic of the highest intensities in the stacked sample. We propose that the lower radio flux density for inclined PGC galaxies is related to a selection effect in the input catalog that should be considered in future stacking experiments of optically-selected spiral galaxies. We do not find a statistically significant change in the low-frequency spectral index with inclination, which is limited by the sensitivity of the VLSS. However, this stacking analysis applied to future surveys below 100 MHz will have the sensitivity to investigate the inclination dependence of free-free absorption as a function of galaxy type.

453.04 – How Galaxy Orientation Affects Measurements of Bulge Velocity Dispersion and the Consequences for the M-Sigma Relation

Jillian M. Bellovary[1], Kelly Holley-Bockelmann[1], Charlotte Christensen[2], Alyson Brooks[3], Fabio Governato[4]

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The scaling relation of central black hole mass and spheroid velocity dispersion (M-Sigma relation) is one of the best-known and tightest correlations regarding black holes and their host galaxies. There has been much scrutiny concerning the difficulty of obtaining accurate black hole measurements, and rightly so; however, it has been taken for granted that measurements of velocity dispersion are essentially straightforward. We examine five Milky Way-like disk galaxies from cosmological SPH simulations and find that line-of-sight effects due to galaxy orientation can affect the value of Sigma by up to 30%, and consequently black hole mass estimates by 0.6 - 1.0 dex. Face-on orientations correspond to systematically lower velocity dispersion measurements, while more edge-on orientations give higher velocity dispersions. This effect may account for some of the scatter in the locally measured M-Sigma relation.

453.05 – IFU Observations of Giant Low Surface Brightness Galaxies

Peter Yoachim[1], Denise Schmitz[1], Sarah Loebman[2], Victor P. Debattista[3], SungWon Kwak[1]
1. University of Washinton, Seattle, WA, United States. 2. University of Michigan, Ann Arbor, MI, United States. 3. University of Central Lancashire, Preston, United Kingdom.

We present optical IFU observations of the Giant Low Surface Brightness Galaxies (GLSBs) Malin 2 and UGC 6614. We argue that these systems are massive ellipticals that have accreted extended disks through mergers rather than normal spiral galaxies with extreme properties. We trace the stellar kinematics of the systems out to 5 effective radii and find the systems are dark matter dominated. Stellar population synthesis shows the central ellipticals and disk systems are both dominated by old stars but are chemically distinct with the disk being very metal poor.

453.06 – Bulge Kinematics of Giant Low Surface Brightness Galaxies

Denise Schmitz[1], Peter Yoachim[1], Sarah Loebman[2], Victor P. Debattista[3], SungWon Kwak[1]
1. University of Washington, Seattle, WA, United States. 2. University of Michigan, Ann Arbor, MI, United States. 3. University of Central Lancashire, Preston, United Kingdom.

Using the Dual Imaging Spectrograph (DIS) on the Apache Point Observatory 3.5m telescope, we have obtained long-slit spectra of the centers of two giant low surface brightness galaxies (GLSBs), Malin 2 and UGC 6614. Comparison of these data with spatially resolved spectra of the disks (presented in a companion poster) will allow us to compare the disk and bulge kinematics and distinguish between possible formation scenarios. Preliminary investigation of these objects has shown that they possess bulges which are morphologically and photometrically similar to typical elliptical galaxies. This suggests that the GLSB disks are the remnants of a high angular momentum accretion event, rather than being an extreme version of a normal spiral or the remnant of a collisional ring galaxy.

453.07 – Burst and Quench? The Life Story of Low Surface Brightness Galaxies

Jason Young[1], Sharon Xuesong Wang[1], Rachel Kuzio de Naray[2]
1. Pennsylvania State Univ., University Park, PA, United States. 2. Georgia State University, Atlanta, GA, United States.

We present a first look at spatially resolved optical/infrared spectral energy distributions (SEDs) of low surface brightness disk galaxies. We have observed a sample of low surface brightness galaxies with the VIRUS-P integral field spectrograph and have combined those observations with archival Spitzer IRAC images to create SEDS. We present these SEDs in the context of different candidate star-formation histories. This easily overlooked class of galaxy comprises up to half of the galaxy population with masses spanning that of the Milky Way, making them cosmologically significant baryon repositories. They are also very different from the more familiar archetypal galaxies in that they have unusually high gas fractions, up to 95%. Yet, they do not represent a distinct class of galaxy, but are simply on the low surface brightness end of a continuum. Our spatially resolved spectra give our analyses a significant advantage over those based on broad-band photometry, which have significant model degeneracies, and those based on whole-galaxy measurements, which average out distinct stellar populations. Additionally, because we analyze our optical spectra, which are sensitive to age indicators such as Lick Indicies and the 4000 angstrom break, in tandem with Spitzer IRAC photometry, which is a direct measurement of the integrated star-formation history, we are able to discriminate between candidate histories with greater confidence than earlier works. We aim to use our analyses to characterize the star-formation histories of galaxies over a range of surface brightnesses near the low end of the observed continuum so that these galaxies can be appropriately placed in the larger context of galaxy formation over cosmic time.

453.08 – Wide-band Jansky Very Large Array polarization observations of M51

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We present new L band (1-2 GHz) multi-configuration Jansky Very Large Array polarization observations of M51. Using this new data set, we are able to, for the first time, perform direct fits to Stokes Q and U of the diffuse polarized emission from external galaxies as a function of wavelength to various depolarization models. The measured polarized emission as a function of wavelength in L band is consistent with Faraday rotation in an external screen in M51's near-side halo. The distribution of rotation measure across M51 can be explained by the presence of a halo magnetic field, which has a bisymmetric plane-parallel component and a coherent perpendicular component. Future observations of M51 below 1 GHz and above 2 GHz will enable one to model its disk and halo field simultaneously.

453.09 – A Study of Supermassive Black Holes and the Properties of Their Host Galaxies

Ismaeel Ahdulla Akhlite Al-Baidhany[1], Marc Seigar[2], Patrick M. Treuthardt[3], Amber Sierra[4], Ben N. Davis[5], Daniel Kennefick[6], Julia D. Kennefick[7], Claud H. Lacy[8]
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Contributing teams: Team 1, Ismaeel , Marc, Patrick, Amber, Team 2,Ben, Daniel, Julia, Claud

Here we selected a sample of Spitzer/IRAC 3.6 um images of 52 galaxies nearly face-on spiral galaxies and used IRAF to determine the ellipticity and major-axis position angle in order to deproject the galaxy images to face-on. A two-dimensional Fast Fourier Transform was then applied to the deprojected images in order to measure the spiral arm pitch angles. In this study: 1-we compared the masses of supermassive black holes (SMBH) estimated by applying the correlations between supermassive black hole mass (MBH) and host- galaxy bulge velocity dispersion (?*) (MBH-?*) relation to those determined using the SMBH mass versus pitch angle relation. Both methods provide an independent determination of SMBH mass and, thereby, provide a SMBH mass estimate. In spite of our results showing a small difference between the mass values, where masses estimated from the MBH – ?* relation are a slightly larger than that from the MBH–P relation, the results are largely compatible between the two relations. 2- We studied a correlation between spiral arm pitch angle (P) and the maximum rotational velocity (Vmax), which was taken from the LEDA database. We found that there is not a tight correlation between spiral arm pitch angle and the maximum rotational velocity (Vmax). 3- We measured the masses of supermassive black holes (SMBHs) by applying the correlations between (SMBHs) and host- galaxy bulge velocity dispersion (?) (MBH-? relation) , where we have taken velocity dispersions (?) from the literature, and we determined the bulge dynamical mass dynamical (Mdyn) using the virial theorem. We found a relation between the bulge dynamical mass (Mdyn) and spiral arm pitch angle. 4-We investigated a new relation based on 2Dbulge-disc decompositions between the spiral arm pitch angles and the bulge luminosities of disk galaxies.

453.10 – The effects of storm fronts over galaxy disks

Daniel C. Smith[1], Curtis Struck[2]
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The existence of partially ionized, diffuse gas and dust clouds at kiloparsec scale distances above the central planes of edge-on, galaxy disks was an unexpected discovery about 25 years ago. Observations showed that this extended or extraplanar diffuse interstellar gas (EDIG) has rotation velocities approximately 10-20% lower than those in the central plane, and has been hard to account for. In a previous publication we presented results of hydrodynamic models, with radiative cooling and heating from star formation. In models with star formation generated stochastically across the disk, we found an extraplanar gas layer is generated as long as the star formation is sufficiently strong but no difference in rotational velocities between the midplane gas and the extra planar gas. We found models that incorporate spiral or bar waves also generate EDIG layers, but only over the wave regions. This partial coverage caused radial as well as vertical motion in the EDIG resulting in the kinematic anomalies observed in galaxies with an EDIG component. In this paper, we present a comparison of this model to recent observations as well as other models that have been proposed to explain the rotational differences.

453.11 – Diffuse Emission in Nearby, Face-on Spiral Galaxies

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X-ray observations of face-on spiral galaxies reveal detectable, diffuse emission present across the face of nearby galaxies. Whether that emission represents hot gas or the emission from unresolved point sources remains to be determined. We present a statistical analysis of long Chandra observations of several nearby spirals to attempt to answer the question. We also compare the X-ray observations with observations from other wavebands. We particularly examine the long Chandra observations of M83 and M51.

453.12 – The Dust Lane Curvature in a Sample of Galactic Bars

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The bars of some disk galaxies are observed to harbor dust lanes that are both offset to the bar major axis and along the leading edges. These dust lanes are related to shocks in the gas flow and correspond to areas of substantial shear, which prevents star formation. A correlation between the measured curvature of these dust lanes and bar strength appears to agree with simulation predictions. Other bar properties, such as axial ratio and pattern speed, are also predicted by simulations to influence the dust lane morphology. The goal of this project is to empirically test if a correlation between dust lane curvature, bar axial ratio, and bar pattern speed exists, while also improving the statistics of previous studies. A sample of barred spiral galaxies with previously estimated pattern speeds and high resolution HST archive images was selected for this investigation. We show the preliminary results of our measurements.

453.13 – The Arecibo Galaxy Environments Survey Isolated Galaxies Sample

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Contributing teams: AGES

The Arecibo Galaxy Environments Survey (AGES) is a neutral hydrogen (HI) survey covering 16 fields and sampling the whole gamut of galaxy environments from voids to clusters. This includes 5 square degree regions around three isolated galaxies: NGC 5523, UGC 2082 and NGC 1156. We here present the results of the AGES observations of the isolated galaxy sample, including our finding that the dwarf:giant ratio is, even with only three galaxies, significantly lower than would be predicted from the field HI mass function.

453.14 – The Unusual Young Supernova Remnant Population in M83

William P. Blair[1, 2], Michael A. Dopita[7], Parviz Ghavamian[4], K. D. Kuntz[1], Knox S. Long[2], Paul P. Plucinsky[5], Roberto Soria[6], P. F. Winkler[3]
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The face-on grand design spiral galaxy M83 (d=4.6 Mpc) is a veritable supernova factory, having generated six known SNe in less than 100 years. Hence, one might expect of order 60 or more supernova remnants (SNRs) less than a thousand years old that might shed light on the poorly understood ejecta-dominated phase of early SNR evolution, as well as many more older, ISM-dominated remnants that should still be visible. We are conducting a multi-wavelength Chandra/Hubble/ground-based campaign to find and characterize the SNRs in M83, concentrating especially on the younger population. HST/WFC3 emission-line data for seven fields covering the bulk of the bright optical disk have allowed us to identify ~50 optical SNR candidates with angular sizes below 0.5" (<11 pc), many with corresponding Chandra X-ray counterparts. However, with the singular exception of the remnant of SN1957D, we are not finding the expected population of ejecta-dominated young SNRs. Rather, most of the young SNRs appear to have quickly evolved into the radiative phase. Gemini-S GMOS spectra of selected objects confirm the lack of observed high velocities or obvious ejecta-enhancement of abundances. This unexpected result implies that the CSM/ISM environments for most young remnants in M83 are very dense, perhaps due in part to the super-solar metal abundances in much of this galaxy. We will show representative data from all relevant data sets that lead us to this conclusion. This work is supported in part by STScI grant HST-GO-12513.01-A and Chandra grant SAO-GO1-12115C to Johns Hopkins University.

453.15 – A VLA Low Frequency Survey of the Supernova Remnant Population in M83

Christopher Stockdale[1], Tyler A. Pritchard[2], William P. Blair[3], John J. Cowan[4], Leith Godfrey[5], James Miller-Jones[6], K. D. Kuntz[3], Knox S. Long[7], Larry A. Maddox[8], Paul P. Plucinsky[9], Roberto Soria[10], Bradley C. Whitmore[3], P. F. Winkler[11]

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We present low frequency observations of the grand design spiral galaxy, M83, using the C and L bands of the Karl G. Jansky Very Large Array (VLA). With recent optical (HST) and X-ray (Chandra) observations and utilizing the newly expanded bandwidth of the VLA, we are exploring the radio spectral properties of the more than 150 radio point sources in M83. These observations allow us to probe the evolution of supernova remnants (SNRs) and to find previously undiscovered SNRs. These observations represent the fourth epoch of deep VLA observations of M83. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities.

453.16 – Reconstructing the stellar mass distributions of galaxies using S⁴G IRAC 3.6 and 4.5 μm images: the conversion from light to mass

Sharon Meidt[1], Eva Schinnerer[1], Miguel Querejeta[1], Glenn van de Ven[1], Dennis F. Zaritsky[2], Reynier Peletier[3], Johan Knapen[4], Kartik Sheth[5]

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Contributing teams: S4G, DAGAL

We present a new approach for estimating the 3.6 μm stellar mass-to-light ratio $?_{3.6}$ in terms of the [3.6]-[4.5] colors of old stellar populations. Our approach avoids several of the largest sources of uncertainty in existing techniques using population synthesis models. By focusing on mid-IR wavelengths, we gain a virtually dust extinction-free tracer of the old stars, avoiding the need to adopt a dust model to correctly interpret optical or optical/NIR colors normally leveraged to assign the mass-to-light ratio $?$. By calibrating a new relation between NIR and mid-IR colors of giant stars observed in GLIMPSE we also avoid the discrepancies in model predictions for the [3.6]-[4.5] colors of old stellar populations due to uncertainties in the molecular line opacities assumed in template spectra. We find that the [3.6]-[4.5] color, which is driven primarily by metallicity, provides a tight constraint on $?_{3.6}$, which varies intrinsically less than at optical wavelengths. The uncertainty on $?_{3.6}$ of ~0.07 dex due to unconstrained age variations marks a significant improvement on existing techniques for estimating the stellar M/L with shorter wavelength data. A single $?_{3.6}=0.6$ (assuming a Chabrier IMF), independent of [3.6]-[4.5] color, is also feasible as it can be applied simultaneously to old, metal-rich and young, metal-poor populations, and still with comparable (or better) accuracy (~0.1 dex) as alternatives. Our $?_{3.6}$ is optimal for mapping stellar mass distributions in S^{4}G/DAGAL, for which we are first constructing a new catalog of images using an Independent Component Analysis technique to isolate the old stellar light at 3.6 μm from non-stellar emission (e.g. hot dust and the 3.3 μm PAH feature). Our estimate should also be useful for determining the fractional contribution of non-stellar emission to global (rest-frame) 3.6 μm fluxes, e.g., in WISE imaging and establishes a reliable basis for exploring variations in the stellar IMF.

453.17 – Exponential Galaxy Disks from Stellar Scattering

Bruce Elmegreen[1], Curtis Struck[2]

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Stellar scattering off of orbiting or transient clumps is shown to lead to the formation of exponential profiles in both surface density and velocity dispersion in a two-dimensional non-self gravitating stellar disk with a fixed halo potential. The exponential forms for both nearly-flat rotation curves and near-solid body rotation curves. The exponential does not depend on initial conditions, spiral arms, bars, viscosity, star formation, or strong shear. After a rapid initial development, the exponential saturates to an approximately fixed scale length. The inner exponential in a two-component profile has a break radius comparable to the initial disk radius; the outer exponential is primarily scattered stars.

453.18 – The Upside Down Assembly of Simulated Disk Galaxies

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The puzzle of disk galaxy formation, and the formation of the Milky Way itself, remains unsolved. We analyze the present-day structure and assembly history of a high resolution hydrodynamic simulation of the formation of a Milky Way-like disk galaxy, from the ``Eris'' simulation suite, dissecting it into cohorts of stars formed at different epochs of cosmic history. The oldest disk cohorts form in structures that are radially compact and relatively thick, while subsequent cohorts form in progressively larger, thinner, colder configurations from gas with increasing levels of rotational support. The disk thus forms ``inside-out'' in a radial sense and ``upside-down'' in a vertical sense. While secular heating and radial migration may influence the final state of each age cohort, the dynamics of each co-eval population generically exhibit only minor evolution since formation. This assembly history is largely responsible for the galaxy's present-day correlations of stellar age with spatial and kinematic structure, which themselves are a good qualitative match to the observed correlations for mono-abundance stellar populations in the Milky Way.

453.19 – Ionized Gas Velocities from Multi-slit Spectroscopy for Nearby, Edge-on Galaxies

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Contributing teams: HALOGAS team

Extra-planar (EP) gas in several spiral galaxies shows a decrease in rotational velocity with increasing height above the disk. The majority of this EP gas likely originates from disk-halo cycling driven by star formation in the disk via galactic fountains, which predict a lagging EP component. However, observations for a handful of galaxies show a steeper gradient than predicted by galactic fountains alone. A possible remedy for this is EP gas originating from infalling material, such as accreted satellites or the IGM. Accreted material with lower initial angular momentum than the disk could contribute to a steeper rotational velocity gradient. Studying the kinematics of EP gas can therefore provide constraints for how widespread accretion may be. We present optical observations and modeling of the ionized EP gas in our sample of 10 nearby, edge-on galaxies. For a subset of our targets, we compare our results to those from the HALOGAS (Hydrogen Accretion in LOcal GAlaxieS) project. HALOGAS is WSRT deep HI survey studying cold gas accretion in the local universe. Our optical observations are from a multi-slit spectroscopic setup on the ARC 3.5m telescope, which allows us to measure velocities of Ha-emitting gas as a function of height above the disk in 11 radial distance bins in a single exposure. RW acknowledges support from NSF grant AST-0908126 and from a grant from Research Corporation for the Advancement of Science.

453.20 – Mass Distribution & Morphology of Simulated Spiral Galaxies

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Contributing teams: Arkansas Galaxy Evolution Survey (AGES), Arkansas High Performance Computing Center (AHPCC)

Results from the literature suggest that quantities based on mass distribution within spiral galaxies (e.g., velocity curves, shear rates, black hole mass) correlate with pitch angle. Despite these findings, no research exists on the relationship between concentration of mass within the dark matter halo or bulge and the pitch angle of spiral galaxies. We are primarily conducting tests to quantify the effects of c_{vir} (virial concentration of dark matter) on the structure of spiral galaxies. Using GalactICS 2008 (based on Widrow, Pym and Dubinski's 2008 model of the Milky Way), we generate initial conditions for spiral galaxy models that vary in ? and a_h (the "cuspiness" of the halo profile and the halo scale radius, respectively). We then evolve these initial conditions over a period of 3 Gyr using the simulation package GADGET-2 (Springel, 2008). We compute quantities of interest at different points of evolution in our models, including pitch angle, and attempt to establish or rule out relationships between them and halo concentration parameters.

453.21 – Molecular gas mass and star formation of 12 Virgo spiral galaxies along the ram pressure time sequence

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The ram pressure stripping is known as one of the most efficient mechanisms to deplete the ISM of a galaxy in the clusters of galaxies. As being affected continuously by ICM pressure, a galaxy may lose their gas that is the fuel of star formation, and consequently star formation rate would be changed. We select twelve Virgo spiral galaxies according to their stage of the ram pressure stripping event to probe possible consequences of star formation of spiral galaxies in the ram pressure and thus the evolution of galaxies in the Virgo cluster. We investigate the molecular gas properties, star formation activity, and gas depletion time along the time from the ram pressure peak. We also discussed the evolution of galaxies in the cluster.

453.22 – The Molecular Gas Properties of M100 as seen by ALMA

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M100 is a nearby "grand-design" barred spiral galaxy in the Virgo cluster. It has abundant molecular gas in its centre, long spiral arms dominating its optical disk and has a relatively face-on inclination (i~30 degrees). Due to its proximity (~16 Mpc) and relatively face-on inclination, M100 is an ideal target for molecular gas studies, and has been the subject of a number of previous interferometric studies in CO with, for example, the Nobeyama mm-wave Array (Sakamoto et al. 1995, 1999), the IRAM interferometer (Garcia-Burillo et al. 1998), and the Berkeley-Illinois-Maryland Association (BIMA) millimeter interferometer array (Regan et al. 2001, Helfer et al. 2003). Over the last two to three years, the new Atacama Large Millimetre/submillimetre Array (ALMA), located on the Chajnantor plateau in northern Chile, has been carrying out a process of Science Verification (SV) as part of its commissioning, and one of the targets was M100, observed in the CO J=1-0 line (ALMA Band 3). This data, as with other SV data, is publicly available. Here, we compare the molecular gas properties of M100, as traced with the ALMA CO J=1-0 data, at a native spatial resolution of ~200 pc, with HI data taken with the Very Large Array (VLA). We describe the integrated intensity maps and compare them to other data from the literature to investigate the variation of the molecular gas, atomic gas and star formation properties - in particular, presenting a spatially resolved star formation law and gas depletion timescale - as a function of distance along the spiral structure.

454 – Molecular Clouds, HII Regions, Interstellar Medium Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

454.01 – Column Density Maps of the I-GALFA HI Survey: Evidence for Dark Gas?

Steven J. Gibson[1], Bon-Chul Koo[2], Kevin A. Douglas[3], Jonathan H. Newton[4], Joshua E. Peek[5], James M. Hughes[6, 1], Mary Spraggs[1], Geumsook Park[2], Ji-hyun Kang[7], Carl E. Heiles[8], Eric J. Korpela[8]
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The gas in galactic disks, including our own, occurs in a wide range of temperatures and densities, most of which are unsuitable for star formation. Somehow, diffuse atomic clouds are collected into colder, denser molecular clouds that can collapse under their own gravity. The molecular condensation process is not directly observable, and the gas itself is often ``dark'' to standard probes like optically thin HI 21cm emission or the CO 2.6mm line. However, the presence of this dark gas can often be inferred from infrared dust emission in excess of what is expected for the observed HI and CO content. We have mapped apparent HI column densities in the Inner-Galaxy Arecibo L-band Feed Array (I-GALFA) survey, which covers a 1600 square degree region at 4-arcminute resolution in the first Galactic quadrant. We compare these ``naive'' HI columns to others derived from Planck first-release CO and dust maps and NE2001 model dispersion measures to identify a number of areas with potentially significant dark gas. We discuss whether optically thick HI or CO-free H2 is more likely to dominate the dark column, and we consider the effects of possible biases on our results. We acknowledge support from the National Science Foundation, the NASA Kentucky Space Grant Consortium, Western Kentucky University, and the Gatton Academy. I-GALFA (www.naic.edu/~igalfa) is a GALFA-HI survey observed with the 7-beam ALFA receiver on the 305-meter William E. Gordon Telescope. The Arecibo Observatory is a U.S. National Science Foundation facility operated under sequential cooperative agreements with Cornell University and SRI International, the latter in alliance with the Ana G. Mendez-Universidad Metropolitana and the Universities Space Research Association.

454.02 – Tracing molecular gas content through optical extinction within nearby galaxies

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We present an estimation of molecular gas content in nearby galaxies derived from their optical extinction. We map the extinction using PMAS integral field spectroscopy in two ways: from the Balmer decrement reddening of H alpha and H beta line maps, and from the stellar continuum reddening. We compare this to the CO emission observed with the IRAM 30m telescope as part of the HERACLES project. We compare these maps at a matched resolution of 13", which corresponds to 7.7×10^{-5} ~kpc physical scales. For each of the eight galaxies in our dataset, we analyze our result pixel-by-pixel for the correlation between extinction and CO emission, and we conclude first that the extinction in a galaxy is a valid method of tracing its CO emission, and second that the Balmer line reddening is a more accurate than the stellar reddening at tracing the molecular gas. Finally, we find that the correlation is better for those galaxies with higher spatial resolution and a higher star formation rate.

454.03 – Molecular Gas in the Andromeda Galaxy

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We present results from an Andromeda Galaxy (M31) survey of star-forming regions based on 24 μm luminosity for H_2O masers, NH_3 (1,1) and NH_3 (2,2) lines, and Hydrogen recombination lines (H66α). Although five H_2O masers were detected in the initial survey of 206 regions towards M31, we do not detect additional H_2O masers in a follow up survey of 300 similar compact 24 μm regions. We do not detect NH_3 (1,1), NH_3 (2,2), or H66α lines in any of the 506 regions. The typical rms noise for 3.3 km s^{-1} channels in individual spectra is 2.5 mJy. Additionally, averaging all 506 spectra, shifted to the correct radial velocity, yields no detection for H2O, NH_3 (1,1), NH_3 (2,2), or H66α. The typical rms noise for 3.3 km s^{1} channels in stacked spectra is 0.13 mJy. The non-detection of NH_3 provides an upper limit on NH_3 integrated flux, NH_3 column density, and corresponding dense gas fraction. We compare the NH_3 integrated flux upper limit with Galactic NH_3 integrated flux data,

scaled to the distance of M31, and find that the M31 NH_3 abundance is consistent with the Galactic NH_3 abundance. We calculate the ratio of NH_3 (1,1) integrated flux to Herschel 500 µm flux density for molecular cloud-sized regions in M31 and the Galaxy. Comparing this ratio between M31 and the Galaxy also indicates that the M31 NH_3 abundance is consistent with the Galactic NH_3 abundance.

454.04 – Massive Cold Clumps in NGC 7538 revealed by Herschel

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Contributing teams: Herschel HOBYS Team

Observations of the high-mass star formation region NGC 7538 taken with the Herschel Space Observatory were made at 70, 160, 250, 350, and 500 micron as part of the Herschel imaging study of OB Yound Stellar objects (HOBYS) Key Programme. Within the one square degree field, we identify 780 dense sources and further analyze 224 of those. We fit spectral energy distributions to the subset of sources and classify 17 objects for further investigation as possible instances of cold starless clumps which may be precursors of high mass star formation. A peculiar feature in the observations is a large, nearly complete ring of material. The ring is of unknown origin and hosts a number of the detected sources.

454.05 – Improved Probing of the Rosette Nebula Superbubble with Faraday Rotation

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In a recent paper Savage et al. 2013, ApJ 765, 42, we reported the results of our investigation of the super bubble associated with the Rosette Nebula (NGC 2244). We made linear polarization measurements of 23 extra-galactic radio sources whose lines of sight passed through or close to the Rosette Nebula. The observations were made at frequencies of 4.4GHz, 4.9GHz, and 7.6GHz using the Karl G. Jansky Very Large Array (VLA). We measured an excess rotation measure (RM) of 50-750 rad m-2 for sources whose lines of sight passed through the nebula. We compared our data with two simple plasma models that can reproduce the magnitude and sign of the measured RM. We argued that one of these models, a wind-blown bubble with an outer shock, better represented our data. However, distinguishing between these models requires measurements on more lines of sight. In NRAO project 12A-039, we observed 11 additional radio sources whose lines of sight pass through the shell of the Rosette Nebula to supplement the previous measurements and to further constrain the simple shell models. The 2012 observations cover two 1.024 GHz bands centered at 4.85GHz and 7.25GHz, with sixteen 128MHz sub-bands. This receiver configuration potentially allows for sixteen measurements of the polarization position angle across the sub-bands, which is a vast improvement over the three polarization position angle measurements of the previous data. We report preliminary results of Faraday rotation measurements for these 11 new lines of sight. We also describe similar Faraday rotation observations of the HII region W4/IC1805 undertaken in NRAO program 13A-035. This research was supported at the University of Iowa by grant AST09-07911 and ATM09-56901 from the National Science Foundation.

454.06 – Evolution of the ISM at z < 1

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z=1 corresponds to a time at which the Universe was roughly half its current age, and is generally agreed to mark a shift in the typical processes involved in galaxy evolution. Galaxy interactions, merger rates, morphologies, and star formation rates (SFRs), for example, can all be said to have exhibited fundamental changes since z=1 (Combes et al. 2013). The underlying processes causing these changes, however, are not very well understood. Several studies (Combes et al. 2011; Combes et al. 2013; Daddi et al. 2010; Geach et al. 2011; Tacconi et al. 2010) have attempted to investigate the evolution of the molecular gas fraction and its influence upon the shift in SFR through CO line surveys . It is hypothesized that the molecular gas fraction should decrease over time as more of this gas is used to form stars. These studies, however, have only been conducted on very small samples, and many focus upon galaxies at specific redshifts or upon very luminous galaxies. It is thus increasingly difficult to discern whether or not the trends indicated by the composite of these studies represent real and definitive relationships concerning the evolution of the molecular gas fraction in "the average galaxy." In addition, direct CO(1-->0) measurements are generally not possible for redshift ranges ~0.3-1 due to issues of instrument sensitivity and spectral coverage. This research attempts to re-examine the evolution of the molecular gas fraction at z<1 by proxy of an examination of dust masses and involves a much larger sample of galaxies (~450 from the COSMOS field) in an attempt to reach definitive conclusions regarding the potential influence of the evolution of the molecular gas fraction upon the evolution of SFRs. This involves fitting SEDs in order to determine dust masses and using a constant factor to convert these dust masses to molecular gas masses. Results are compared to previous literature and the expected trend (i.e., increase in SFR and in molecular gas fraction with increase in z). Suggestions for future evaluation and potential future applications of

this method of estimating molecular gas masses are also discussed.

454.07 – Examining the Initial Conditions of Star Formation Through Dense Gas Kinematics

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Simulations of star forming molecular clouds give the ability to compare realities and expectations, providing a look at the relative importance of different physical processes. We obtained five sample cores from a global, turbulent, molecular cloud simulation and six perspectives for each core, giving us a total of thirty datacubes. The purpose of this analysis was to compare kinematic simulations of dense gas in protostellar cores to both single-dish and interferometer observations. To accomplish this, we convolved the simulation data with a single-dish beam corresponding to the IRAM 30m, and used synthetic interferometer observations corresponding to the CARMA array in D configuration. We then constructed moment maps for each perspective and derived velocity gradients across the Moment 1 maps and average line widths across the Moment 2 maps. Velocity gradients gave bulk motion in the envelope, and line widths gave velocity distribution along the line of sight. These values were then compared to observations of existing protostellar cores taken with the aforementioned telescopes using the Kolmogorov-Smirnov (KS) statistical test to find the probability that the simulation and observation samples came from the same parent distribution. In general, we had low probabilities that our null hypothesis was false, indicating that it was likely that, for both single-dish and interferometer, the simulations and observations were not describing the same kinematics. We conclude that the difference between the simulation and observations was due to differing initial conditions in the molecular clouds in which they formed, which gives insight into performing more accurate simulations in the future. In particular, the extreme broadness of line widths for the single-dish simulations indicates an excess of supersonic turbulence driving strong infall in the cores. Also, although we wanted to interpret velocity gradients as rotation, they did not really seem to trace rotation.

454.08 – Probing interstellar extinction in the Tarantula Nebula with red giant stars

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We have studied the properties of the interstellar extinction in a field of 3? × 3? located about 6? SW of 30 Doradus in the Large Magellanic Cloud (LMC). The observations with with the WFPC 2 camera on board the Hubble Space Telescope in the U, B, V , I and H bands show the presence of patchy extinction in this field. In particular, the colour–magnitude diagram (CMD) reveals an elongated stellar sequence, running almost parallel to the main sequence (MS), which is in reality made up of stars belonging to the red giant clump (RC) and spread across the CMD by the considerable and uneven extinction in this region. This allows us to derive in a quantitative way both the extinction law in the range 3 0008 000 Å and the values of the absolute extinction towards more than 100 objects, thereby setting statistically significant constraints on the properties of the extinction in this area. We find an extinction curve considerably flatter than the standard Galactic one and than those derived before towards a sample of sight lines in the LMC. The value of RV = 5.6 that we find implies that in this region large grains dominate. Comparing the extinction towards the individual RC stars and a similar number of stars in the upper MS reveals that the latter span a narrower range of E(B V) values, contrary to what has been found elsewhere in the LMC. We are now extending these studies to 30 Doradus itself and to a large portion of the Tarantula nebula using existing HST observations at ultraviolet, optical and near infrared wavelengths.

454.09 – The Distribution of Oxygen in the Magellanic Clouds

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Young metal atoms, after they have been violently ejected into the ambient ISM from their dead, massive birth stars, are faced with some options. Some may stay close to home, some may travel within their galaxies, some are taken in by newly forming stars along the way, and others may venture outside of their galaxies altogether. We have been investigating the fates of the metal atoms in galaxies by measuring gas-phase abundances using HII regions in the Magellanic Clouds. We find that the oxygen abundances of their HII regions are significantly lower than what we expect, based on common assumptions about the net oxygen yield from stars, and given their total stellar content. From this oxygen deficiency, we infer that there is a significant loss of metals from the ionized ISM in the Magellanic Clouds. Future research will trace the spread of these missing metals, possibly to other gaseous phases within the galaxies, or within the Milky Way halo. Our findings also lay the groundwork for comparing the metal abundances of the HII regions to those of neutral HI gas along the same lines-of-sight,

and testing long-standing assumptions of uniform chemical abundances across gas phases in the ISM.

454.10 – Interstellar Organics, the Solar Nebula, and Saturn's Satellite Phoebe

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The diffuse interstellar medium inventory of organic material (Pendleton et al. 1994, Pendleton & Allamandola 2002) was likely incorporated into the molecular cloud in which the solar nebula condensed. This provided the feedstock for the formation of the Sun, major planets, and the smaller icy bodies in the region outside Neptune's orbit (transneptunian objects, or TNOs). Saturn's satellites Phoebe, Iapetus, and Hyperion open a window to the composition of one class of TNO as revealed by the near-infrared mapping spectrometer (VIMS) on the Cassini spacecraft at Saturn. Phoebe (mean diameter 213 km) is a former TNO now orbiting Saturn. VIMS spectral maps of Phoebe's surface reveal a complex organic spectral signature consisting of prominent aromatic (CH) and aliphatic hydrocarbon (CH2, CH3) absorption bands (3.2-3.6 μm). Phoebe is the source of a huge debris ring encircling Saturn, and from which particles (~5-20 μm size) spiral inward toward Saturn. They encounter Iapetus and Hyperion where they mix with and blanket the native H2O ice of those two bodies. Quantitative analysis of the hydrocarbon bands on Iapetus demonstrates that aromatic CH is ~10 times as abundant as aliphatic CH2+CH3, significantly exceeding the strength of the aromatic signature in interplanetary dust particles, comet particles, and in carbonaceous meteorites (Cruikshank et al. 2013). A similar excess of aromatics over aliphatics is seen in the qualitative analysis of Hyperion and Phoebe itself (Dalle Ore et al. 2012). The Iapetus aliphatic hydrocarbons show CH2/CH3 ~4, which is larger than the value found in the diffuse ISM (~2-2.5). Insofar as Phoebe is a primitive body that formed in the outer regions of the solar nebula and has preserved some of the original nebula inventory, it can be key to understanding the content and degree of processing of that nebular material. There are other Phoebe-like TNOs that are presently beyond our ability to study in the organic spectral region, but JWST will open that possibility for a number of objects. We now need to explore and understand the connection of this organic-bearing Solar System material to the solar nebula and the inventory of ISM materials incorporated therein.

454.11 – Investigation of Interstellar Formation Routes Using Molecular Abundance Ratios of C3H2O Isomers

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Molecular isomers provide a unique tool for probing interstellar regions, as molecular abundance ratios contain information about the history and conditions of the region, acting as a chemical fingerprint. Comparing abundances of complex molecules in an attempt to extract this information proves to be difficult, however, for many sources. Due to complex source structure and vast networks of molecular interactions, it is exceedingly difficult to create accurate models (Quan & Herbst 2007, A&A 474, 521). However, molecular isomer abundance ratios may provide a way to slowly disentangle the puzzle (Lovas et al. 2010, JMS 264, 10). As isomers are the same size and present a similar level of chemical complexity, comparing their abundances will provide information about both their formation chemistry and the energetics of the formation region. Toward this end, we have fully characterized the spectra of the three isomers of C3H2O toward the well known molecular region Sgr B2. Evidence for the detection of the isomers cyclopropenone (c-C3H2O) and propynal (HCCCHO) is presented, along with evidence for the non-detection of the the lowest energy isomer, propadienone (CH2CCO). We interpret this to show that chemical formation pathways, which may be under kinetic control, have a more pronounced effect on final isomer abundances than thermodynamic effects such as the minimum energy principle (Lattelais et al. 2009, ApJ 696, L133). A brief discussion of possible formation routes and analysis of their implications is also presented.

454.12 – Molecular Lines in NGC660

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NGC660 (z = 0.003) is a highly unusual Luminous Infra-Red Galaxy (LIRG) having a component that is strongly warped out of the plane of its main disc, plus an outer quasi-polar ring. An Arecibo spectral survey from 1.1 to 10 GHz was made in Nov-Dec, 2012, following the surprising discovery of excited-OH emission lines at 4750 and 4765 MHz in Dec 2008, which were not present in Dec 2007 and Aug 2008. These spectral features brightened between 2008 and 2012, with excited-OH absorption lines developing at 4660 MHz. All three transitions showed multiple components. A strong new continuum component had similar temporal development, and HSA-VLBI imaging of this show an outburst to be occurring in the nucleus of the galaxy. The new spectral survey used the Double Position Switching technique, with the Mock spectrometer as back-end. Interesting detections from the survey include multiple radio-recombination hydrogen lines, formaldehyde (H2CO) absorption at 4829 MHz, ground-state satellite OH lines at 1612 and 1720 that are conjugate, the satellite 6049-MHz excited-OH line, and the excited-CH line at 4848 MHz. Other possible detections, including apparent HCN (v2=1) emission at

4488 MHz, are being investigated.

454.13 – WHAM Southern Sky Survey early results: Ionized gas in the Scutum-Centaurus Arm

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We present early results from the Wisconsin H-Alpha Mapper (WHAM) Southern Sky Survey, the completion of the first kinematically-resolved, all sky survey of diffuse H-Alpha emission from the Galaxy. We show spectroscopic maps of H-Alpha and [S II] lambda 6716 emission from the warm ionized medium in the Scutum-Centaurus Arm in the inner Galaxy. We measure the scale height of the ionized gas in the arm, finding it to be less than that observed in the Perseus Arm. The [S II]/Halpha line ratio is enhanced in faint sightlines. The trends in the line ratio are most consistent with emission from in situ photoionized gas in which the physical conditions are primarily a function of density. WHAM is supported by the NSF through grant AST 1108911.

454.14 – Pilot Search for 54-MHz Maser Emission from Interstellar Hydroxyl Using LOFAR

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Contributing teams: The LOFAR Collaboration

We present the results of the most sensitive search to date for the two 54-MHz spectral lines of the hydroxyl (OH) molecule. These are the preliminary results of a larger, planned observational campaign. The splitting of the rotational ground state of the hydroxyl molecule gives rise to the four familiar 1.7-GHz transitions by which OH is known in the interstellar medium. There are also two magnetic-dipole transitions among these states at frequencies of 53.2 MHz and 55.1 MHz. These 54-MHz transitions have never been detected astronomically. Because of the relative weakness of the magnetic-dipole emission process, it is expected that only maser emission will generate a detectable 54-MHz signal. Two previous searches have been conducted by other authors with other instruments toward Galactic sources of known 1720-MHz OH maser emission: three sources were searched at 55.1 MHz and two other sources were searched at 53.2 MHz, resulting in upper limits of approximately 30 Jy for spectral channels of 2 km/s in width. In preparation for our future observational campaign that will apply the unprecedented sensitivity of LOFAR to the search for 54-MHz OH emission, we conducted a pilot project using six hours of Commissioning Time. These observations employed 21 48-element stations and produced a spectral resolution of approximately 0.5 km/s for both the 53.2- and 55.1-MHz lines. This spectral resolution is a considerable improvement over previous searches since it is suitable both for resolving the characteristically narrow width of maser lines and for identifying radiofrequency interference. In our pilot observations, no emission was detected at either frequency with an upper limit of approximately 3 Jy. We observed the Galactic sources W75N and W3(OH), neither of which have been searched previously at either frequency. We discuss the astrophysical implications of these sensitive non-detections. LOFAR, the Low Frequency Array designed and constructed by ASTRON, has facilities in several countries, that are owned by various parties (each with their own funding sources), and that are collectively operated by the International LOFAR Telescope (ILT) foundation under a joint scientific policy.

454.15 – A Survey of the Local Interstellar Medium Using COS Observations of Nearby White Dwarfs

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Observations of objects with well-studied UV continua provide excellent backdrops against which the spectra of intervening ISM clouds may be discerned. White dwarfs are an exceptional example of this. As such, we present analyses performed on a sample of more than 90 archival COS spectra of nearby white dwarf stars. These were observed as part of a large scale survey to ascertain the extent to which they might be polluted from circumstellar debris disk accretion (Gaensicke et al. 2012). The high sensitivity of the COS spectra and the quality of the WD stellar model spectra make this data set a prime sample for studying the properties of the local ISM. The spectra are analyzed to determine the characteristics of the absorption from any intervening ISM clouds as detected in CII, NI, OI, SiII, SiIII, and SII. From these measurements we can evaluate the kinematics, abundances, electron density, ionization structure, and size of the absorbing cloud. Given the size of this sample, and the growing number of LISM sight lines observed, we can place limits on the distance of the absorbing

clouds.

454.16 – Dust in the Rosette Nebula

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We present detailed wide field maps of visible light extinction on lines of sight sampling with a resolution of 4 arcseconds across the Rosette Nebula, and an analysis of the spatial distribution of dust responsible for the observed spectrum. Flux calibrated, narrow bandwidth Hα and Hβ observations were used to construct hydrogen spectral line strength ratio maps, providing measurements of dust-induced reddening throughout the region. Comparisons with thermal dust emission from WISE mission data inform an analysis of the possible spatial distribution of dust throughout this nearby star forming region.

454.17 – What is the G2 cloud?

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The apparently low mass of the G2 cloud prompts questions about whether substellar gas clouds can persist as long-lived, stable entities? And, if so, what their internal structure is, and how G2 might have looked before falling under the influence of Sgr A*? I will present structural models of sub-stellar clouds which prove to be very durable. These entities are also dense, cold, and almost transparent, so they would be very difficult to detect - a form of baryonic dark matter. The Galaxy could harbour a large population of such objects, with the G2 cloud being unusual only in respect of its orbit.

454.18 – A Spectral Analysis of the Interstellar Medium Using Sagittarius B2 as the Bright Continuum Source

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We report detections of several molecular gas tracers in clouds along the line of sight to the Galactic center. Spectra were obtained from the Robert C. Byrd Green Bank Telescope as part of the PRIMOS survey, using Sagittarius B2 as the bright background continuum source to see these diffuse clouds in absorption. Clouds along the line of sight to Sgr B2 are distinguished by their distinct line-of-sight velocities. This study identified four previously known clouds and detected four new clouds. Detected molecules include cC3H2, CCS, HCS+, SiO, 29SiO, H2CO, H213CO, HC3N, CH3CN, NH2CHO, CH3CHO, CH2CHCN, and CH3OH. Clouds along the line of sight to Sgr B2 are distinguished by their distinct line-of-sight velocities. This study identified four previously known clouds and detected four new clouds. The absorption line technique is shown to be an effective means of determining the small scale structure of the inner Galaxy.

454.19 – A Survey of Hidden Molecular Clouds in the Milky Way

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Contributing teams: I-GALFA Survey Consortium

It is critical to understand the internal processes of galaxies, such as star formation, which occurs in the coldest, densest interstellar clouds. Unlike stars, these clouds are difficult to detect in visible light, but radio and infrared telescopes allow observations of the gas and dust particles they contain. In regions of the galaxy, ambient neutral atomic hydrogen gas is forming molecules, a sign of condensing clouds. We are interested in these clouds as precursors to stellar evolution where molecular hydrogen is critical. However, it is difficult to observe molecular hydrogen directly. Thus, proxy detectors such as carbon monoxide (CO) are used as indicators of molecular hydrogen. This method is not flawless. Through a comparative study, we propose substantial dark molecular hydrogen is not detected with current methods. We use far-infrared dust emission measurements from the IRAS and the Planck satellites for two independent measures of total column density. We trace visible gas column density using radio 21-cm hydrogen emission from Arecibo and 3-mm CO data from multiple surveys. Without dark gas, the dust and visible gas column densities should be equivalent. As this is not the case, there is evidence for dark molecular hydrogen overlooked in standard observations.

454.20 – Configuration of the local interstellar magnetic field

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Contributing teams: IBEX Team

The discovery of the Ribbon of energetic neutral atoms by the Interstellar Boundary Explorer (IBEX) provides a new and unexpected diagnostic of the direction of the local interstellar magnetic field (ISMF). The IBEX Ribbon forms where the interstellar magnetic field draping over the heliosphere is perpendicular to the sightline. We have shown that the direction of the interstellar magnetic field close to the Sun, obtained from starlight polarized in the interstellar medium (ISM), is consistent with the ISMF direction that is traced by the IBEX Ribbon. In this presentation we show that new optical polarization data indicate that the local ISMF has a smoothly varying component stretching from the first to the third galactic quadrant. Both the ISMF direction and the kinematics of local interstellar gas within tens of parsecs support an interpretation where the local interstellar clouds are a fragment of the expanding Loop I superbubble.

454.21 – Time Variation of Cosmic Ray Arrival Directions

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Experimental data from the IceCube Neutrino Observatory have been used to characterize the anisotropy in the arrival directions of muons produced in cosmic ray air showers. The anisotropy can be fairly well described as a superposition of a dipole and quadrupole of unknown origin in celestial equatorial coordinates. It is also expected to be described as a dipole associated with the Compton-Getting effect in a coordinate system fixed with respect to the Sun. We utilized IceCube data collected from 2008 through 2011, containing 3.69 x 10^10 events with a median cosmic ray particle energy of 20 TeV. We limited our analysis to data from four azimuthal regions, allowing the rotation of the Earth to trace out a periodic signal. We used a Lomb-Scargle periodogram to approximate a frequency spectrum from the event rates. The frequency spectrum contained four peaks with a significance level greater than 5?, including a peak at 0.997 day^-1 that is consistent with a sideband caused by modulation of the solar dipole. If further analysis confirms this modulation, interference between the solar and sidereal time frames will need to be considered in future analyses of the anisotropy. This work was partially supported by the National Science Foundation's REU program through NSF Award AST-1004881 to the University of Wisconsin-Madison.

454.22 – The Molecular Gas - Star Formation Connection in an Extended Ultraviolet (XUV) Disk

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Studies of star formation beyond the optical radius in galaxies allow us to test empirical relations and theoretical models in extreme conditions with low gas density and a low molecular fraction. However, most previous studies are missing molecular gas, which is the component of the interstellar medium out of which stars form. Therefore, we used the Institut de Radioastronomie Millimétrique 30m to measure a deep upper limit for the molecular hydrogen gas density ($?_{H2}$) in one star forming region in the extended ultraviolet (XUV) disk of NGC 4625. Our upper limit is an order of magnitude below the typical sensitivity limit of molecular gas surveys in nearby galaxies. We also included published $?_{H2}$ measurements or upper limits for regions in the outer disk of NGC 6946. We compared these $?_{H2}$ measurements to star formation rates derived from

Hα, far-UV (FUV), and 24 micron data. We found that star forming regions in the outer disks of NGC 4625 and NGC 6946 are consistent with the same molecular hydrogen Kennicutt-Schmidt law that applies within the optical radius, independent of whether we used Hα or FUV as the star formation rate tracer. Furthermore, we measured ages of 1 - 7 Myr for the regions by comparing the Hα-to-FUV flux ratio to stellar population evolution models. Based on these ages and the typical molecular cloud destruction time of a few × 10 Myr, we expect molecular gas to be present in all the regions we studied. We can test this hypothesis with deeper CO data. Deeper data may also enable us to use the presence or absence of molecular gas as an evolutionary probe to break the degeneracy between, for example, age and stochasticity as explanations for the low average Hα-to-FUV flux ratios in XUV disks.

454.23 – Characterizing the Dense Gas in the Eagle and Pelican Pillars

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We observed two regions with molecular pillars, the Eagle and the Pelican, in order to understand the morphology of dense gas in these structures. Molecular pillars are formed in HII regions at the boundary between ionized gas and molecular clouds through the effects of photoionization, ablation, and recombination. Two sets of models exist for the formation mechanism of the pillars: (1) the growth of radiative hydrodynamic instabilities and (2) shadowing of the ionization front due to clumps in the molecular cloud. We have CARMA observations of the two sources in HCN J=1-0, N_2H^+ J=1-0, HCO^+ J=1-0 and CS J=2-1 with resolutions of 9x6'' for the Eagle and 4x4'' for the Pelican. The dense gas follows the structure outlined in the optical images and seen in CO emission, throughout the pillars, with an increase in emission in the heads of the pillars. The differencing morphologies among the molecules are consistent with typical photo-disassociation region behavior. The velocity field shows a distinct gradient from head-to-tail for the majority of the pillars. We find that the morphology and the kinematics of the pillars are consistent with the shadowing model.

454.24 – X-ray Properties of the Peculiar HII Region IC 131 in M33

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Contributing teams: XMM-Newton Legacy Survey of M33 Team

Recent XMM-Newton and Chandra observations of nearby galaxies conducted with high angular resolution have detected a wealth of sources with a diverse set of spectral properties. A prior Chandra observation of the nearby spiral galaxy M33 has detected X-ray emission from the HII region IC 131 that is unusually hard compared to the X-ray emission detected from other HII regions (Tuellmann et al. 2009). The nature of this hard X-ray emission remains uncertain: the emission may originate from a thermal plasma with a temperature of ~4 keV (which corresponds to an electron temperature that is unlikely to be attained in an HII region) or synchrotron radiation (though it is uncertain whether cosmic-ray acceleration models normally applied to supernova remnants may be extended to a structure like IC 131 which has a physical size of 200 pc). As part of the XMM-Newton Legacy Survey of M33, we have obtained and analyzed X-ray observations made of IC 131 by XMM-Newton and extracted MOS1+MOS2+PN spectra of the source. We have jointly fitted these extracted spectra (along with an ACIS spectrum of the source) using a thermal model and non-thermal models, including a simple power law and the synchrotron models SRCUT and SRESC (we have constrained the latter two models using observed radio properties of the region). We obtain statistically acceptable fits using each of these models. We examine the derived values of the fit parameters in conjunction with ancillary data to determine which physical model most realistically explains the origin of the observed emission. The results of our spatial and spectral analysis will be presented and discussed.

454.25 – Examination of the Applicability of Quasi-time-dependent Truncated CJ Shock Wave Models in Interstellar Molecular Clouds

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Young stellar objects generate energetic bipolar molecular outflows that collide with the surrounding gas and dust within a molecular cloud core and subsequently form shock waves in star-forming regions. Although much theoretical work has been done on steady shocks, observations of bipolar outflows have revealed their ages to be as young as 10^2-10^4 years (e.g., Hartigan et al. 2001), which are much less than the typical time it takes for a multifluid magnetohydrodynamic (MHD) shock wave to reach a steady state (~10^5 yr). Thus time-dependent modeling of these flows is required. An approximate way of treating non-steady shocks in single-fluid gas dynamics is the so-called truncated shock method (e.g., Raymond 1979). This method was adopted and extended to weakly ionized magnetized interstellar clouds by LeSaffre et al. (2004), who suggested

that stable multifluid MHD shocks could be modeled as truncated quasi-steady CJ shocks, wherein a steady jump ("J-type") shock model in the neutral fluid is essentially "glued together" with a steady continuous ("C-type") shock model in the charged fluid and magnetic field. The truncated CJ model serves as the fundamental basis for several recent theoretical studies of the chemistry and line emission in molecular outflows and non-stationary shocks (e.g., Gusdorf et al. 2008; Flower & Pineau des Forêts 2012). Here we examine the region of applicability for truncated quasi-steady CJ shock models in weakly ionized molecular clouds by comparing them to fully time-dependent multifluid MHD simulations calculated using a recent numerical method presented in Ciolek & Roberge (2013).

454.26 – Diffusion, Self-Similarity, and the Formation of Multifluid Shock Waves

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A chemically active outflow (CAO) is a region of shock-heated gas where the outflow from a protostar impacts ambient cloud core material. Modeling the molecular line emission from CAOs is a primary tool for inferring the chemical diversity of star-forming regions. As these regions typically contain magnetic fields and are only weakly ionized, the models necessarily require magnetohydrodynamical simulations of multifluid shock waves, wherein the charged and neutral particles behave as separate, interacting fluids. Because the outflows are typically younger than the time needed (>10,000 yr) to attain steady flow, the simulations must also be time dependent. Unfortunately the initial conditions for such a simulation are ambiguous, there being no way to know the initial state from which a particular shock evolved. In this paper we show that the charged fluid component and the magnetic precursor to a young multifluid shock wave evolves rapidly (on a time scale typically ~ 0.1 yr) into a quasi-self-similar (QSS) form which does not depend on the initial conditions. Consequently the QSS solution serves as an effective initial state for time-dependent shock models. We give an analytic expression for the QSS solution, in a form that includes the possible dynamical effects of charged dust grains.

454.27 – A Multi-wavelength Analysis of Cold Evolving Interstellar Clouds

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Since galaxies are essential parts of the universe's structure, it is important to understand their inner workings, including star formation and related processes in the interstellar medium (ISM). The ISM is made up of atomic and molecular gas, mostly hydrogen, with a small amount of other elements and solid dust particles. Interstellar gas is found with a wide range of temperatures and densities, but only the coldest, densest clouds can undergo gravitational collapse to form new stars. The manner in which such clouds condense out of warmer, more tenuous material is not understood but may follow a phase transition from atomic to molecular hydrogen. We have assembled a large data set of atomic and molecular spectral line image cubes and infrared dust maps to track this phase transition and any corresponding changes in gas temperature, density, and related properties in different parts of our own Galaxy. We will present an overview of our technique and preliminary results from the analysis.

454.28 – The Northern Intermediate-Velocity Molecular Clouds (IVMCs): Distances and Environments.

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The three-dimensional structure of the ISM towards the Northern IVMCs is presented based on an analysis of reddening using Sloan Digital Sky Survey photometry. Maps are created for regions covering the Draco clouds, the IVC pair at (l+b) = 135+51 and 135+54, and for IREC 306. These IVMCs are found within the complex of intermediate and high velocity HI clouds that span the Northern 2nd Galactic Quadrant.

454.29 – Polarization Properties and Magnetic Fields in NGC 6946

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We present new broad-band radio polarization observations at 6cm and 13cm of NGC 6946, obtained using the Westerbork Synthesis Radio Telescope (WSRT), which we combine with previous WSRT-SINGS 18cm and 22cm broad-band data. The combined dataset provides highly sensitive diagnostics of the internal depolarization across the galaxy. Using model fitting, we determine likely mechanisms for depolarization in different regions of the galaxy. We compare these mechanisms with

WNM and CNM properties from HI observations to better understand the role magnetic fields play in the turbulent ISM and star formation. We also present a new Faraday dispersion map of NGC 6946 that probes more extreme Faraday depths than previous observations, displaying new features of the line of sight magnetic field.

454.30 – A multi-wavelength study of the GSH 006-15+7: A local Galactic supershell

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GSH 006-15+7 is a Milky Way supershell discovered by Moss et al. (2012). This supershell shows large shell-like structures in H I velocity maps. We have presented and analyzed C IV emission line map which is generally detected in supernova remnants as well as other multi-wavelength maps of this supershell region. While stronger dust extinction appears at the H I shell region than its boundaries, excessive soft X-ray filament is shown at the left inner boundaries of the supershell in the 0.75keV and 1.5keV soft X-ray band maps. It implies a collision between young supernova shock wave internally generated and its inner dense wall. Moreover, it is most likely that the bright parts of the 0.75keV and 1.5keV band maps as well as C IV map in the range of l~[0°, 12°], b~[-13°, -5°] are associated with the supershell because they are well confined with the boundaries of the supershell. The intensity variation for the C IV, Si II* and 0.75keV band soft X-ray emission of the interior of the supershell indicates that the inner temperature of the Supershell changes from 106 K at the top to 10^4 K at the bottom. The bottom of the supershell seems to be developed by the early supernova(s) in the supershell creation era and cooled its inner temperature down by ~10^4 K for a long-time of 15 Myr. On the contrary, the top of the supershell seems to be formed and maintained by the follow-up supernova(s) or stellar winds and still kept its inner temperature of ~10^6 K. Our interpretation can support the fact that the supershell is the outcome of many generations of stars within a region.

454.31 – Far-Ultraviolet Study in the Ophiuchus cloud complex and the Upper Scorpius subgroup of the Sco OB2 association

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We have constructed a far-ultraviolet (FUV) continuum map and a molecular hydrogen fluorescent map of the Ophiuchus cloud complex, one of a well-known birthplace of stars using FUV Imaging Spectrograph (FIMS). The FUV intensity varies significantly across the whole region. FUV flux is bright on Sco OB2 association where Hα emission is also bright, while FUV flux seems to be heavily absorbed by the dense cloud of rho-Ophiuchus cloud, where the dust extinction level is high. It seems that molecular hydrogen fluorescence correlates well with CO emission throughout whole region. Dust extinction also shows a relationship with molecular hydrogen fluorescence. Using the result of interstellar radiation field calculation, we found that fluorescence in this region is likely to depend more on abundance of molecular hydrogen, directly connected to dust extinction. We also found that the H2 fluorescent emission for a certain PDR has a log-normal distribution. We also showed that Interstellar radiation field also can be log-normally distributed. Based on star catalog and stellar model, we calculate interstellar radiation field up to 1kpc from the Sun. At the Sun, the ISRF was ~1.6 G0 when the extinction was considered while it was ~5.4 G0 without the extinction effect on ISRF. We also applied this result of ISRF calculation to two kinds of studies: (1) determination of cloud distance and (2) parameter constraint in PDR simulation. As a line of research to understand spatial characteristics of molecular hydrogen fluorescence in this region, we present the result of PDR simulations using CLOUD for some individual regions that are suspected of PDRs (Photodissociation Regions).

454.32 – Power law structure of the interstellar medium: Fractal dimension of the HI, CO and mid-IR in nearby galaxies

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The properties of turbulence in galaxies are a fundamental part of our understanding of the interstellar medium (ISM) as a complex and dynamic system. Turbulence changes the proportions of gas in the warm and cold phases and affects the regulation of star formation. Supersonic turbulence is known to have many sources, ranging from supernovae and stellar winds to the interaction between rotational shear and galactic magnetic fields. However, the details of these mechanisms and their interactions are not well understood. Several studies have linked turbulence with self-similarity, a property of the mathematical objects known as fractals. This study compares the fractal dimension of contours of three components of the ISM in nearby galaxies. These components sample the atomic, molecular and gas phases by way of the 21cm line of atomic Hydrogen (HI), the CO J=2?J1 transition and mid-IR 70μm dust emission. The THINGS (HI), SINGS (IR) and HERACLES (CO) surveys share a common galaxy sample from which five galaxies are selected for analysis. We present the results of this study.

454.33 – Kinematic Results From a Systematic Search for Infall Signatures Towards the Starless Core Population in the Perseus Molecular Cloud

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We present the results of a survey searching for infall signatures toward 72 starless cores in the Perseus molecular cloud. Observations of the ground state rotational transitions of HCN, HNC, and H13CN were carried out using the 12-m radio telescope on Kitt Peak operated by the Arizona Radio Observatory. All three molecules are tracers of dense molecular gas. HCN 1-0 is an excellent infall tracer, with its three hyperfine lines probing different optical depths. We examined the spectra for signs of infall by comparing observed line asymmetries with the velocity peak of the optically thin isotopologue H13CN. We find that there is an excess of blue asymmetries, but clearly self-absorbed profiles are rare (< 20%). We compare typical measures of asymmetry such as ?v and skewness. By comparing the number of blue asymmetric and blue skewed profiles to the number of class II protostars, we find a range for the observable collapse lifetime of 6x10^4-2x10^5yrs, which is commensurate with the gravitational free-fall time (5x10^4yrs) for the observed central densities of Perseus starless cores. The best infall candidates all have observed masses that are above the Jeans mass. We calculate the infall speeds for the best collapse candidates and compare their dynamics to other known collapsing starless cores. This project was observed by The University of Arizona Undergraduate Astronomy Club.

454.34 – Into the Darkness: Interstellar Extinction Near the Cepheus OB3 Molecular Cloud

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We present the results of a followup investigation to a study performed by Massa and Savage (1984, ApJ, 279, 310) of the properties of UV interstellar extinction in the region of the Cepheus OB3 molecular cloud. That study was performed using UV photometry and spectro-photometry from the ANS and IUE satellites. We have extended this study into the IR, utilizing the uniform database of IR photometry available from the 2MASS project. This is a part of a larger program whose goal is to study the properties of extinction in localized regions, where we hope to find clues to dust grain growth and destruction processes through spatial correlations of extinction with distinct environmental properties. Similarly to Massa and Savage's UV results, we find that the IR extinction properties on the Cepheus OB3 region vary systematically with the apparent proximity of the target stars to the molecular cloud. We also find that the UV extinction and the IR extinction are crudely correlated. The methodology leading to these results and their implications are discussed.

454.35 – Radio Recombination Line Emission in Sgr B2 Main and North: Detecting Broad RRLs

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We have observed Sgr B2 Main and North in the 1.3 cm and 7 mm continuum in all three hybrid configurations with the EVLA. By comparing the new (2012) data with archival (1989) observations at the same frequencies, we have detected significant flux density changes in four of the ultracompact sources (F1, F3, F10.303 and K3). We have also observed Sgr B2 Main and North in the H66α, H68α H53α and H52α radio recombination lines (RRLs). Here we present the 7 mm continuum emission, and preliminary RRL results from the Sgr B2 Main and North regions, with particular attention to the line emission from the sources with detected flux density changes between 1989 and 2012.

454.36 – A Possible Protostar in IGGC 22

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We present evidence of a possible protostar in IGGC 22 (Inner Galaxy Gas Clump 22). The project utilized CO J = 7 – 6 spectra from the HIGGS (Herschel Inner Galaxy Gas Survey) project to search for high-velocity red and blue wing line emission, an indication of possible outflow. These red and blue wings were spatially mapped over the IGGC 22 region and discovered to have geometry consistent with bipolar outflow. The moment maps of this region indicate that the wings are not due to overall cloud rotation, and the likely jet ages are consistent with a protostar in its primary accretion phase. Furthermore, the location of the candidate protostar is consistent with shock-induced star formation. Further analysis is needed, but we consider this to be encouraging evidence of star formation within the IGGC 22 region.

454.37 – Temperature, Density, and Collision Rates in the IC63 Nebula

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The IC 63 reflection nebula provides a near-by, well characterized, laboratory for a number of astrophysical processes, including radiation driven chemistry, gas dynamics and grain alignment physics. To provide improved constraints on many of these phenomena we have acquired high-resolution maps of tracers of the gas density and temperature in the nebula. We will present initial results from mapping the (1,1) and (2,2) rotational inversion transitions in ammonia with the Green Bank Telescope, which trace the gas temperature, and observations of HCO+ (J=1-0 and J=3-2) with IRAM 30m/Plateau de Bure, which probe the gas density. Specifically, we discuss the impact of the variations in gas-grain collision rates on the dust grain alignment and the resulting polarization of background starlight that passes through the nebula.

454.38 – NH₂D in Orion KL: Results from ALMA, EVLA, and IRAM

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We present results from interferometric image cubes of several deuterated ammonia (NH_2D) transitions, observed between 2009 and 2012 in the nearby star-forming nebula Orion KL. These data spatially and kinematically resolve NH_2D into distinct emitting regions, and include lines at 239 and 216 GHz observed in ALMA Science Verification, at 110 GHz observed by IRAM, and at 43 and 25 GHz observed by the EVLA. This unexampled multi-interferometer sample features diverse upper excitation levels from ~20 to 150 K above ground, a range sensitive to the source temperature in Orion KL. Thus, our data are well suited to clarifying the formation pathways of deuteration in the various spatial components of this nebula. In the gas phase, NH_2D can only be produced at kinetic temperatures ~10 K, above which its molecular building blocks are destroyed. Our preliminary results suggest an NH_2D rotational temperature of ~160 K near the infrared source IRc7, providing unambiguous evidence that NH_2D is not currently being produced in the gas phase. This result is consistent with previous suggestions that the NH_2D was perhaps preserved on grain surfaces when the gas was cold, and subsequently evaporated into the warming gas to yield the elevated NH_2D/NH_3 column ratio that we observe. We will present results from other spatially resolved components of NH_2D in Orion KL, and discuss ramifications for models of Orion KL's formation history. We gratefully acknowledge collaboration with C. Favre, N. Brouillet, D. Despois, and T. Jacq (LAB, U. Bordeaux).

454.39 – Far Ultraviolet Observations of the ? Ophiuchi HII region

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The star ? Ophiuchi (HD 149757) is one of the brightest massive stars in the northern hemisphere and was widely studied in various wavelength domains. We report the analysis results of far ultraviolet (FUV) observations with other wavelengths for around ? Ophiuchi. We study the correlation of between multi wavelength observations. We have developed a Monte Carlo code that simulates dust scattering of light including multiple encounters. The code is applied to the present Oph HII region to obtain the geometrical information of dust such as distance and thickness. Also We apply three-dimensional photoionization code to model Wisconsin Hα Mapper observations of the H II region surrounding the star.

454.40 – A Multi-Wavelength Study of Water Maser-Emitting Regions in the Andromeda Galaxy

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We present a comparative multi-wavelength analysis of water maser emitting regions and non-maser luminous 24 micron star forming regions in the Andromeda galaxy (M31). We performed photometric measurements of Spitzer data at 24 microns and Herschel data at 70 and 160 microns. Additionally we examined the published H-alpha luminosities, dust temperature, and star formation rate for the maser and non-maser samples. We investigate the relationship between water masers and their hosts using statistical tools including the Kolmogorov-Smirnov (K-S) test and principal component analysis. The results of the K-S test on the maser and non-maser sample using the H-alpha luminosities, 24 and 70 microns flux densities, dust temperature, and star formation rate show that the masers and non-maser samples are drawn from different populations. Additionally, we performed principal component analysis on the maser sample to reduce the dimensionality of the data by finding a new set of variables that removes most of the variance present in the sample. The ensemble of water masers in M31 are described mainly by a positive correlation between infrared flux densities at 24, 70, and 160 microns, temperature, and star formation rate. The positive correlation among various star formation tracers for maser regions indicates that there seem to be additional unexamined candidate maser sites in M31.

454.41 – Molecular Hydrogen as a Finite-density and Temperature Indicator

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Infrared observations have discovered a variety of objects, including filaments in the Crab Nebula and cool-core clusters of galaxies, where H_2 the 2.121 µm line is far stronger than nearby H I lines. A variety of processes could be responsible for this emission. Although many complete shock or PDR calculations of H_2 emission have been published, we know of no simple calculation that shows the emission spectrum and level populations of thermally excited low-density H_2. We present a range of purely thermal collisional simulations, corresponding to constant gas kinetic temperature but different densities. We consider the cases of predominantly atomic and molecular regions. The resulting excitation diagrams show that excitation temperatures are sometimes smaller than the gas kinetic temperature except at densities where the level populations have gone to LTE. Considering only commonly observed IR lines, the population distribution at low densities for the v=0 manifold could be misinterpreted as thermal but at too low a kinetic temperature. The excitation diagrams at low densities have a curvature for the v=0 manifold but not the v=1, 2 manifolds. This mimics the classic signature of continuum fluorescent excitation of the molecule. The excitation diagrams are discontinuous between different vibrational energy levels at low density and this could be used as a density diagnostic. Differences between the low-density thermal and the fluorescent or shocked cases could be observed if enough levels are detected.

454.42 – Vibrationally Excited Molecular Hydrogen Near Herschel 36

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We present the first high resolution UV spectra toward Herschel 36, a Trapezium-like system of high-mass stars contained within the Lagoon Nebula (M8, NGC 6523). The spectra reveal extreme ro-vibrational excitation of molecular hydrogen in material at a single velocity or very small range of velocities, most likely the largest ever seen in UV absorption spectra. While the velocities of the highly excited H_2 lines are consistent within each observation, it appears that they underwent a ?60 km s^{-1} redshift during the 3.6 years between observations. In neither case does the velocity of the highly excited material match the velocity of the bulk of the line-of-sight material which appears to mostly be in the foreground of M8. Recent work shows unusually excited CH and CH^+ lines and several unusually broad Diffuse Interstellar Bands (DIBs) towards Herschel 36. Along with the H_2 excitation, all of these findings appear to be related to the extreme environment within ?0.1 pc of the massive young stellar system.

454.43 – OH^+ and H_2O^+: Probes of the Molecular Hydrogen Fraction and Cosmic-Ray Ionization Rate

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Contributing teams: PRISMAS, WISH

The fast ion-molecule chemistry that occurs in the interstellar medium (ISM) is initiated by cosmic-ray ionization of both

atomic and molecular hydrogen. Species that are near the beginning of the network of interstellar chemistry such as the oxygen-bearing ions OH^+ and H_2O^+ can be useful probes of the cosmic-ray ionization rate. This parameter is of particular interest as, to some extent, it controls the abundances of several molecules. Using observations of OH^+ and H_2O^+ made with HIFI on board *Herschel*, we have inferred the cosmic-ray ionization rate of atomic hydrogen in multiple distinct clouds along 12 Galactic sight lines. These two molecules also allow us to determine the molecular hydrogen fraction (amount of hydrogen nuclei in H_2 versus H) as OH^+ and H_2O^+ abundances are dependent on the competition between dissociative recombination with electrons and hydrogen abstraction reactions involving H_2. Our observations of OH^+ and H_2O^+ indicate environments where H_2 accounts for less than 10% of the available hydrogen nuclei, suggesting that these species primarily reside in the diffuse, atomic ISM. Average ionization rates in this gas are on the order of a few times 10^{-16} s^{-1}, with most values in specific clouds above or below this average by a factor of 3 or so. This result is in good agreement with the most up-to-date determination of the distribution of cosmic-ray ionization rates in diffuse molecular clouds as inferred from observations of H_3^+.

454.44 – Thermal OH emission and Dark Gas in the Galaxy

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Analyses of the far-IR continuum emission from dust and the gamma-ray emission from cosmic-ray interactions with gas have recently revealed the presence of extensive clouds of ``dark gas'' in the Galaxy. This dark gas is essentially invisible in 21-cm HI and 3-mm CO emission. It surrounds all nearby dense molecular clouds and appears to form a ``bridge'' to the larger-scale distribution of atomic gas. The spatial distribution of this dark gas has much in common with the ubiquitous faint OH emission in the Galaxy discovered recently in a ``blind'' mini-survey in the Cepheus-Cassiopeia region with the Onsala radio telescope. The OH data in that survey suggests that there is at least a factor 2 more H2 present than has been found via the CO emission. We also report on a new blind pilot survey under way using the GBT on the same L, B grid as the CfA CO survey in this part of the Galaxy

454.45 – Spitzer 8μm Emission as a Tracer of Neutral Gas in the Large Magellanic Cloud

Tony H. Wong[1, 2], Rui Xue[1], Barbara Whitney[2], Fabian Heitsch[3], Annie Hughes[4], Alberto D. Bolatto[5], Thomas Robitaille[4]
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Contributing teams: MAGMA team

We examine the utility of 8 micron PAH emission as a tracer of neutral gas in the LMC, by comparing the Spitzer SAGE imaging with lower resolution CO and HI imaging, pencil beam UV absorption sight lines, and radiative transfer modeling of simulated clouds. We discuss under what conditions the 8μm emission is sensitive primarily to the UV radiation field and under what conditions it can be used to trace column density.

454.46 – Ice Formation and Grain Growth in the Quiescent Medium of the Lupus Molecular Clouds

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Infrared photometry and spectroscopy of background stars reddened by the Lupus molecular cloud complex are used to determine the properties of the grains and the composition of the ices before they are incorporated into circumstellar envelopes and disks. H2O ices form at extinctions of A_V=2.1+/-0.6. Such a low ice formation threshold is consistent with the

absence of nearby hot stars. Overall, the Lupus clouds are in an early chemical phase. The abundance of H2O ice (2.3+/-0.1 10^-5 relative to N_H) is a factor of 3-4 lower compared to dense envelopes of YSOs. CO is not fully frozen out, and a low solid CH3OH abundance is consistent with that. Furthermore it is found that the grains in Lupus experienced growth by coagulation. The mid-infrared continuum extinction relative to A_K increases as a function of A_K. Most Lupus lines of sight are well fitted with extinction curves corresponding to R_V~3.5 and R_V~5.0. The ?_9.7/A_K ratio follows that of dense cores for lines of sight with A_K>1.0 mag. Below 1.0 mag, values scatter between the dense and diffuse medium ratios, indicating that local conditions matter in the process that sets the ?_9.7/A_K ratio. This process is likely related to grain growth, but not to ice mantle formation. Conversely, ice mantles form on grains before the process of grain coagulation has started.

454.47 – Micro-Spec: an Integrated, Direct-Detection Spectrometer for Far-Infrared and Sub-Millimeter Astronomy

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Many space-based observatories, such as Spitzer and Herschel, have opened the far-infrared (IR) window to the universe, revealing rich line and continuum spectra from objects ranging from interplanetary dust particles to galactic mergers and young galaxies in the early universe. Micro-Spec (μ-Spec) is proposed as a novel technology concept to enable new discoveries in the far-IR spectral range. μ-Spec will be a high-sensitivity, direct-detection spectrometer operating in the 450-1000 μm regime. It will have two antenna arrays, one for transmitting and one for receiving, and superconducting microstrip transmission lines for power division and phase delay. Using superconducting materials reduces losses at a minimum, thereby providing background-limited sensitivity (noise equivalent power, NEP, less than 3x10^-21 W/√Hz) at a resolution R~1200, potentially making μ-Spec four orders of magnitude more sensitive than its most capable predecessors. Materials being investigated for the development of the instrument transmission line and detectors include niobium and niobium-titanium nitride for the former, and molybdenum nitride for the latter. In addition, the instrument will be integrated on a four-inch-diameter silicon chip. Such a dramatic size reduction is made possible by the fact that silicon has a refraction index three times that of vacuum, thereby allowing the transmission lines to be shorter than in vacuum by a factor of three. For all these reasons, μ-Spec can become an important capability under the low background conditions provided by space telescopes such as the space infrared telescope for cosmology and astrophysics SPICA, possible Explorers and cryogenically-cooled balloons. The discussion will illustrate a point design developed for initial demonstration with a 30% efficiency due to losses to other diffraction orders. Design variations on this implementation will be shown that lead to near-unity efficiency and will be the basis of future instruments. Models to analyze the properties of the superconductors will also be described along with transmission data used to test and validate the models.

455 – Elliptical Galaxies Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

455.01 – EVIDENCE FOR A CONSTANT IMF IN EARLY-TYPE GALAXIES BASED ON THEIR X-RAY BINARY POPULATIONS

Stephen E. Zepf[1], Thomas J. Maccarone[2], Arunav Kundu[3, 4], Anthony H. Gonzalez[5], Bret Lehmer[6, 7], Claudia Maraston[8]

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A number of recent studies have proposed that the stellar initial mass function (IMF) of early type galaxies varies systematically as a function of galaxy mass, with higher mass galaxies having steeper IMFs. These steeper IMFs have more low-mass stars relative to the number of high mass stars, and therefore naturally result in proportionally fewer neutron stars and black holes. In this paper, we specifically predict the variation in the number of black holes and neutron stars in early type galaxies based on the IMF variation required to reproduce the observed mass-to-light ratio trends with galaxy mass. We then test whether such variations are observed by studying the field low-mass X-ray binary populations (LMXBs) of nearby early-type galaxies. These binaries are field neutron stars or black holes accreting from a low-mass donor star. We specifically compare the number of field LMXBs per K-band light in a well-studied sample of elliptical galaxies, and use this result to distinguish between an invariant IMF and one that is Kroupa/Chabrier-like at low masses and steeper at high masses. We discuss how these observations constrain the possible forms of the IMF variations and how future Chandra observations can enable sharper tests of the IMF.

455.02 – Isolated Early-type Galaxies in the 2dFGRS

Christopher R. Fuse[1], Cameron Lamir[1]
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Isolated galaxies are systems that have experienced limited external perturbations, thus the properties of these galaxies are largely due to internal processes. The features of isolated early-type galaxies (IEGs) provide a baseline from which to compare early-type systems residing in higher-density environments. We use the Two-Degree Field Galaxy Redshift Survey (2dFGRS) and the NASA Extragalactic Database (NED) to identify IEGs in the nearby universe. Search criteria in the 2dFGRS were chosen to insure that the IEGs have remained separated from neighboring galaxies for the majority of their lifetimes. Isolated galaxies are chosen utilizing a minimum projected physical separation of 1 Mpc from any neighboring non-dwarf galaxy brighter than Mb = -16.5 mags. A minimum redshift separation of 350 km/s between a candidate galaxy and a neighboring was imposed to further insure the candidate's isolation. Early results of the search for isolated early-type galaxies in the southern sky are presented.

455.03 – Listening to Shells: Galaxy Masses from Disrupted Satellites

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Our ability to measure the dynamical mass of an individual galaxy is limited by the radial extent of the luminous tracers of its potential. For elliptical galaxies, it is difficult to go much beyond two effective radii using integrated light. Appealing to particle tracers like globular clusters has allowed for mass measurements out to ten effective radii. The extended atomic-gas disks of spiral galaxies allow one to measure rotation curves well beyond the optical disk to a few effective radii; however, such mass measurements are limited to a single plane and can often be confused by warps. As surface-brightness limits have pushed ever deeper, the revealed abundance of disrupted satellites in galaxy halos may present a unique opportunity for determining the enclosed mass at very large radii (more than five effective radii), provided our technology is up to the challenge. Here, we discuss the prospect of using integrated light spectroscopy of tidal shells to measure the masses of individual galaxies at redshifts of up to 0.1. Our study considers the limitations of current and projected instrumentation on 4-, 10-, and 30-meter class telescopes. The observational constraints are indeed very stringent, requiring both high sensitivity (with V-band surface brightness limits below 25 mag per square arsecond) and high spectral resolution (R>10k), whereas spatial resolution is effectively irrelevant. Bigger is not necessarily better for our application because of the limited field-of-view (FOV) of large telescopes, which dramatically limits their total grasp. We find the two most-promising setups are (1) a large FOV (1 square arcminute) integral-field unit (IFU) on a 4-meter class telescope and (2) a multiplexed suite of small FOV (10 square arcseconds) IFUs on a 10- or 30-meter class telescope. Two prospective instruments that may meet these requirements are WEAVE, an instrument currently planned for the William Herschel Telescope at La Palma, and an OPTIMOS-EVE-like instrument on the E-ELT.

456 – Dark Matter & Dark Energy Poster Session
Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

456.01 – The Dark Matter Contribution to the Galactic Diffusion Gamma Ray Emission

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Observations of Galactic diffuse gamma ray emission (DGE) made by the Fermi Large Area Telescope (LAT) allows a detailed study of cosmic rays and the interstellar medium. However diffuse emission models of the inner Galaxy under-predict the Fermi-LAT data at energies of a few GeV and hint at possible non-astrophysical sources including dark matter (DM) annihilation and decay. We present a study of the possible emission component from DM using the high-resolution Via-Lactea II N-body simulation of a Milky Way-sized DM halo. We generated full-sky maps of DM annihilation and decay signals that includes modeling of the adiabatic contraction of the DM density profile and different models of the Sommerfeld enhancement effect for the case of DM annihilation. We compared our result with the DGE models produced by the Fermi-LAT group at different sky regions, namely, the Galactic center, high Galactic latitudes, and the Galactic anti-center. Our result provide additional templates to fit the observational data and thus possible approaches to constrain DM models.

456.02 – Status and Prospects for Indirect Dark Matter Searches with the Fermi Large Area Telescope

Eric Charles[1]
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Contributing teams: Fermi-LAT Collaboration

During the first five years of operation of the Fermi Large Area Telescope (LAT) the LAT collaboration has performed numerous searches for signatures of Dark Matter interactions in both gamma-ray and cosmic-ray data. These searches feature many different target types, including dwarf spheroidal galaxies, galaxy clusters, the Milky Way halo and inner Galaxy and unassociated LAT sources. They make use of a variety of techniques, and have been performed in both the spatial and spectral domains, as well as via less conventional strategies such as examining the potential Dark Matter contribution to both large scale and small scale anisotropies. To date no clear gamma-ray or cosmic-ray signal from dark matter annihilation or decay has been observed, and the deepest current limits for annihilation exclude many Dark Matter particle models with the canonical thermal relic cross section and masses up to 30 GeV. In this contribution we will briefly review the status of each of the searches by the LAT collaboration. We will also discuss the limiting factors for the various search strategies and examine the prospects for the future.

456.03 – Dark Matter Content of Dwarf Galaxies, Measured from Tidal Debris

Jacob Bauer[1], Matthew Arsenault[1], Travis Desell[2], Malik Magdon-Ismail[1], Heidi J. Newberg[1], Matthew Newby[1], Colin Rice[1], Jeffrey Thompson[1], Steve Ulin[1]
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We use maximum likelihood estimation (MLE) to find the best parameters for the mass, size, and mass/light ratio of dwarf galaxies that are the progenitors of tidal streams. An N-body simulation, including both dark matter and stars, is run for each set of candidate parameters. The distribution of stars in the resulting tidal stream is compared to either a simulated tidal stream with known progenitor properties, or observations of stars in a tidal stream. Massively parallelized sets of n-body simulations using the BOINC computing project, MilkyWay@Home, allow probing of an extensive likelihood surface. We show evidence that this approach is feasible, and report the results of initial trials on real streams. This research is supported by NSF grant AST AST 10-09670.

456.04 – Probing Gravity in the High-Redshift Universe with HETDEX

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The addition of dark matter and dark energy to general relativity is degenerate with a modification of the dependence of curvature on the stress-energy tensor in the absence of exotic sources of matter and energy; it is thus valuable to explore the latter as a potential improvement over the former. Though it is inherently difficult to distinguish existing evidence for the general relativity paradigm from that of its more promising alternatives, such theories are associated with different histories

for the largely unexplored growth of structure. Zhang, et al. (2007) have enabled discrimination of these possibilities via a new observable parameter E_G and have predicted the efficacy of several future astronomical surveys to determine its value. In this work, we examine the ability of the Hobby Eberly Telescope Dark Energy Experiment (HETDEX) to contribute to calculations of this indicator of gravity at the highest redshifts ($1.9 < z < 3.5$). We show that a prerequisite of such a measurement is a deeper understanding of the nature of Lyman-α emitting galaxies (LAEs). If HETDEX can constrain the statistical properties of the typical LAE velocity dispersion, then it will not be necessary to wait for the (as yet unplanned) next generation of high-resolution spectrographs to obtain a test of general relativity in the high-redshift universe.

456.05 – Measurements of D_A and H at z=2.4 from the SDSS-III/DR11 BOSS Lyman-alpha sample

David J. Schlegel[1], Timoth\'ee Delubac[2], Nicol\'as G. Busca[3], James Rich[2], Stephen J. Bailey[1], Julian Bautista[3], Andreu Front[4, 1], David Kirkby[5], Jean-Marc Le Goff[2], Matthew Pieri[6], Anze Slosar[7], Eric Aubourg[3], Michael Blomqvist[5], Adam S. Bolton[8], Arnaud Borde[1], William Carithers[1], Rupert A. Croft[9], Kyle S. Dawson[8], Daniel Eisenstein[10], Jean-Christophe Hamilton[3], Shirley Ho[9], David W. Hogg[11], Khee-Gan Lee[12], Britt Lundgren[13], Daniel Margala[5], Jordi Miralda-Escudé[14, 15], Adam D. Myers[16], Pasquier Noterdaeme[17], Nathalie Palanque-Delabrouille[2], Isabelle Paris[17, 18], Patrick Petitjean[17], Nicholas Ross[19], Graziano Rossi[2], Matteo Viel[20, 22], David H. Weinberg[21], Martin White[1, 23], Christophe Yeche[2]

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Contributing teams: Sloan Digital Sky Survey III (SDSS-III) Baryon Oscillation Spectroscopic Survey (BOSS)

We present the most precise measures of the Baryon Acoustic Oscillation (BAO) scale at z=2.4 from the 3-dimensional clustering of the Lyman alpha forest. The Hubble parameter (BAO scale along the line of sight) is measured to 3% precision. The angular diameter distance (perpendicular to the line of sight) is measured to 5% precision. These results make use of the Sloan Digital Sky Survey III (SDSS-III) Data Release 11 (DR11), with 135 000 high-redshift quasar spectra covering 9000 square degrees. This study supersedes the previous measurements of Busca et al. (2013) and Slosar et al. (2013) with a gain of nearly a factor of three in the amount of Lyman alpha spectra data. We also perform a detailed study of the covariance matrix of the Lyman alpha correlation, which is validated with both simulations and subsampling (data-only) techniques.

457 – Large Scale Structure, Cosmic Distance Scale Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

457.01 – MEGA-SH0ES: Revising the Cepheid Distance to NGC 1365

Samantha L. Hoffmann[1], Lucas M. Macri[1], Adam G. Riess[2, 3]
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Contributing teams: MEGA-SH0ES Team

The MEGA-SH0ES project aims to obtain accurate and precise distances to host galaxies of type Ia supernovae within 50 Mpc, as part of an effort to measure the Hubble constant with a total uncertainty of 2%. We recently observed NGC 1365, host of SNeIa 2012fr, with HST/WFC3. We conducted a variable search that combined the WFC3 images with archival WFPC2 data to discover Cepheid variables. We present preliminary results of our analysis, including an update on the 52 variables discovered by the HST Key Project, and the H-band P-L relations needed to obtain a robust distance to this galaxy.

457.02 – MEGA-SH0ES: A Cepheid distance to M101 based on WFC3 H-band photometry

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Contributing teams: the MEGA-SH0ES team

The MEGA-SH0ES project aims to obtain accurate and precise distances to host galaxies of type Ia supernovae within 50 Mpc, as part of an effort to measure the Hubble constant with a total uncertainty of 2%. We recently obtained HST/WFC3 observations of the Pinwheel galaxy (M101), which hosted SNeIa 2011fe. We combined the new images with archival ACS data and discovered over 1000 Cepheid candidates with periods ranging from 3 to 80 days. We present preliminary results from this analysis, including H-band P-L relations which are critical to obtain a robust distance to this galaxy.

457.03 – The Tip of the Red Giant Branch Distance to NGC 1316 Hosting Four Type Ia Supernova and the Hubble Constant

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Type Ia supernovae (SNe Ia) are known to be a powerful standard candle so that play an important role in cosmic distance scale research. Since the discovery of the cosmic acceleration, the need for more accurate calibration of SNe Ia luminosity is increasing. So far, the luminosity calibrations of SNe Ia have been done mainly using a population I distance indicator, the Cepehid variables. However, current calibrations of SNe Ia peak luminosity show a sizable scatter. We started the luminosity calibration of SNe Ia using the population II distance indicator the tip of the red giant branch (TRGB). We present the estimation of the TRGB distance to NGC 1316 which is one of the most prolific producers of SNe Ia, hosting four SNe Ia. We obtain VI photometry of resolved stars in the halo of this galaxy from archival Hubble Space Telescope image data. We derive absolute maximum magnitudes of 3 normal SNe Ia (SN 1980N, SN 1981D, and SN 2006dd) in this galaxy. By combining this result and our previous luminosity calibrations based on TRGB analysis for 3 additional SNe Ia (SN 1989B in M66, SN 1998bu in M96, and SN 2011fe in M101), we derive a value of the Hubble constant. We discuss the implication of our results in relation with the calibration of optical and near-infrared maximum magnitudes of SN Ia and the Hubble constant.

457.04 – The Detection of Megamasers to Identify Supermassive Black Holes

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We identified supermassive black holes through the detection of water megamasers in a survey of several hundred galaxies. Spectra were obtained from the Robert C. Byrd Green Bank Telescope, and a Gaussian curve was fit for each galaxy that had an emission line that exceeded three sigma above the noise. The parameters from the Gaussian fit were used to determine the masses of the black holes assuming edge-on accretion disks approximately 0.1 pc in radius. The subsample of megamaser detections provides a target list for future Very Long Baseline Interferometry measurements to map the accretion disks and

determine the full set of orbital parameters. This not only provides accurate measurements of black holes masses, but also allows for the accretion disks to be used as standard rulers for determining the geometric distances to these systems, and thus determine the Hubble Constant independent of other steps in the distance ladder.

457.05 – The Corona Borealis Supercluster - I: Observational Analysis of the Inter-Cluster Dynamics

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We present the results of a dynamical analysis of the core of the Corona Borealis Supercluster (CSC), a highly dense and compact supercluster at z ? 0.07. Expanding on work presented in a recent paper (Batiste & Batuski, 2013), we use data from the Sloan Digital Sky Survey to assess the current dynamical state of the core of the CSC. The Fundamental Plane relation for early-type galaxies is used to determine redshift independent distances to seven clusters in the densest portion of the CSC, with mean accuracy in the relative distance estimates of 4%. Peculiar velocities for each of the seven clusters, determined using these distance estimates, indicate significant extended bound structure in the CSC. We find evidence for two collapsing regions, with some indication that these regions are not dynamically isolated but are in fact bound to each other. Comparing our results with simulations of the core of the CSC (Pearson & Batuski, 2013), we find that significantly more mass is required to bind the structure than is present in the clusters, suggesting a large inter-cluster matter component. We assess the likelihood that this additional mass could be accounted for by field galaxies, and investigate the possibility of an inter-cluster dark matter component as an explanation of our observations. Comparison of the observational analysis with these simulations suggests that the two bound regions identified in our analysis are likely bound to each other, and that the core of the CSC consists of at least five clusters, and has likely reached turnaround and is in collapse.

457.06 – The Corona Borealis Supercluster - II: Mass Estimation & Simulations

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Recently, Pearson & Batuski (2013) found that there should be little chance of finding extended bound structure in the Corona Borealis supercluster (CSC) if most of the mass is contained within the clusters themselves. However, Batiste & Batuski (2013) found evidence for CSC being in a state of collapse through a Fundamental Plane (FP) analysis. The contradiction of the results suggests strongly that there is a substantial matter component outside of the clusters. Using methods developed by Small et al. 1998, Reisenegger et al. 2000, Dünner et al. 2007, as well as a method we developed ourselves based on the spherical collapse model, we find evidence for between 1.91 and 13.9×10^{16} h^1 M™ in the CSC region. The lower end of this mass range would mean there is about twice as much mass outside of the clusters than within the clusters themselves, similar to the finding of Proust et al. 2006 for the Shapley supercluster (SSC). Assuming an inter-cluster matter component of 3.8×10^{16} h^1 M™ (Small et al. 1998), and line-of-sight peculiar velocities implied by the FP at present, our simulations show that there is a ~70% chance of the entire supercluster being gravitationally bound.

457.07 – A Extragalactic Spectral Survey Of The SSA22 Field

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In this work we present the VLT VIMOS MOS and Keck DEIMOS spectra of ~300 new extragalactic sources in the field of the high redshift (z~3.09) proto-cluster SSA22. The objective is to get a more complete multi-wavelength catalog of the SSA22 field. We compare our results with the current spectroscopic surveys on the sky area of SSA22. Additionally, we analyze the emission and spacial distribution of the Lyman Break Galaxies (LBGs) and the X-ray sources with new template-matched spectroscopic redshifts.

457.08 – The galaxy environment of a QSO at z~5.7

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High-redshift quasars are believed to reside in the most massive halos in the early Universe and should therefore be located in fields with overdensities of galaxies, which are thought to evolve into galaxy clusters seen in the local Universe. However, despite many efforts, no unambiguous relation between galaxy overdensities and z ~ 6 quasars has been found, which can possibly be attributed to the difficulty of finding galaxies with accurate redshifts in the quasars' vicinity. So far, overdensity searches around z ~ 6 quasars are based on studies of continuum dropout galaxies, which probe a redshift range of Delta z ~ 1. This range is large enough to select galaxies which may not be physically related to the quasar. In this study, we use deep narrow-band imaging to study the environment of the z=5.72 quasar ULAS J0203+0012. The redshift range probed by our narrow band selection is Delta z ~ 0.1, significantly narrower than continuum dropout searches. This is the first time that Lyman alpha emitters (LAEs) are searched for near a z ~ 6 quasar, to provide clues on the surroundings of quasars at the end of the epoch of reionization. The main result of this work is that no enhancement of LAEs has been found in the surroundings of ULAS J0203+0012, several explanations and interpretations are discussed.

457.09 – Weak Lensing with Galaxy Kinematics

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Weak lensing is weak because the shear signal is much smaller than the noise set by the broad distribution of intrinsic galaxy shapes. We describe a technique that can reduce shape noise by an order of magnitude using spatially-resolved spectroscopy to derive kinematic maps of source galaxies. Shear oriented along the principle axes of a rotating disk induces an offset from the Tully-Fisher relation after inclination corrections, while shear applied at an angle to the disk skews the kinematic axes relative to the photometric axes. Existing multi-object optical spectrographs and IFUs have the spatial and spectral resolution to measure this effect at high signal-to-noise. We discuss science applications ranging from high resolution cluster mass mapping to cosmic shear, including the statistical and systematic uncertainties which can be competitive with and complementary to traditional shear surveys. Notably, the need for photometric redshifts is eliminated, while biases due to shear calibration and intrinsic alignments can be significantly reduced.

457.10 – Baryon Acoustic Oscillations in Lyman Alpha Forest - Quasar Cross-Correlations

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University, University Park, PA, United States. 20. Brookhaven National Laboratory, Upton, NY, United States. 21. Osservatorio Astronomico di Trieste, Trieste, Italy. 22. INFN/National Institute for Nuclear Physics, Trieste, Italy. 23. University of Chicago, Chicago, IL, United States. 24. Universidad de Chile, Casilla, Chile.

We investigate the signal of BAO in the cross-correlations between SDSS III-BOSS DR10 and DR11 quasars and Lyman Alpha Forest. We present two independent analyses that follow slightly different methodologies. In one, we fit the BAO using DR10 data only following multipole methods described in Xu et al. 2012 adapting to the fact that Lyman-Alpha forest is negatively biased, while in the other analyses, we analyze DR11 data following methodologies in Font-Ribera et al., 2012 and Kirkby et al. 2013. In the two analyses, we use different treatments of the Lyman Alpha Forest, different fitting methodologies and found consistent cosmological results. The expected signal-to-noise is weaker than the Lyman-Alpha Forest auto-correlations, however this will be a test of principle of finding BAO in cross-correlations, where systematics can be more easily mitigated. This method also applies to future surveys with medium/dense coverage of multiple tracers in similar redshift range, such as SDSS IV, DESI, WFIRST and EUCLID.

457.11 – Mapping 3D Large-Scale Structure at z ?2 with Lyman-α Forest Tomographic Mapping

Khee-Gan Lee[1], Joseph F. Hennawi[1], Martin White[2, 3], Rupert A. Croft[4], Jason X. Prochaska[8], David J. Schlegel[3], Nao Suzuki[5], Jean-Paul Kneib[7], Stephen J. Bailey[3], David N. Spergel[6], Hans-Walter Rix[1], Michael A. Strauss[6]
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The Lyman-α (Lyα) forest absorption at z>2 traces the underlying dark-matter distribution, and with a sufficient density of background sightlines can be used to create 3D tomographic maps of large-scale structure. Since the useful Lyα forest in each sightline spans ?400-500 h^{-1}Mpc, Lyα forest tomography can efficiently map out large-scale structure at z?2. The Cosmic Lyman-Alpha Program for the Tomographic Reconstruction of Absorption Probes (CLAPTRAP) will be the first survey to attempt this technique. We aim to obtain spectra for a background grid of faint quasars and bright LBGs at 2<z<3 at a limiting apparent magnitude of g=24. At this depth, the sources are separated by transverse comoving distances of d? ? 3 h^{-1}Mpc, allowing a 3D map with similar 3 h^{-1}Mpc resolution to be reconstructed from the data. In a recent paper, we have found that spectra with S/N ? 4 per Å are sufficient to make excellent-quality tomographic maps that clearly trace the underlying dark-matter distribution at overdensities of order unity. This requires integrations of several hours on moderate-resolution spectrographs mounted on existing 8-10m telescopes, such as LRIS on the Keck-I telescope and VIMOS on the Very Large Telescopes. We aim to observe ?1500-2000 background sources over 1 sq deg of the COSMOS field with Lyα forest coverage over 2.0<z<2.4, which would map out a total comoving volume of ?$10^6 h^{-3}$Mpc^3, equivalent to the zCOSMOS and DEEP2 galaxy redshift maps out to z?1. The total time requirement is 16 nights on either VLT-VIMOS or Keck-LRIS. The resulting tomographic maps will be the first 3D maps of large-scale structure at z>1. In conjunction with the rich multi-wavelength data from the COSMOS survey, these maps will facilitate the study of galaxies in the context of the large-scale environment, reveal the topology of large-scale structure at high-redshifts, and allow the direct detection of galaxy protoclusters at the intersections of the cosmic web. The spectra will also be used to measure the Lyα forest auto-correlation at <10h^{-1}Mpc scales, which will place constraints on the properties of the intergalactic medium.

457.12 – Red Galaxy Structures Toward a Large Quasar Group Field

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Contributing teams: LQG Team

We present data from deep FUV-NUV-griz images toward a 2 sq degree region in the Clowes-Campusano Large Quasar Group field, which contains structures of quasars on the >100 Mpc scale at z~0.8 and z~1.2. Large Quasar Groups may be the signal posts for galaxy structures analogous to superclusters at high redshift. Using the six band photometry, we calculate photometric redshifts for red-selected galaxies to identify supercluster-size structures, and compare their locations with the quasars in the field.

457.13 – The Very Small Scale Clustering of SDSS-II and SDSS-III Galaxies

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The very small scale clustering of galaxies can tell us about their spatial distribution within dark matter halos. To study the local universe, we measure the very small-scale angular clustering of galaxies in volume-limited luminosity samples drawn from the SDSS DR7. These angular scales correspond to 20 to 500 kpc at the median redshift of the $M_r < -20$ galaxy sample. We model this clustering using mock galaxy catalogues produced from the LasDamas simulations and the Halo Occupation Distribution (HOD) framework, assuming a flexible density profile of satellite galaxies within halos. We find that luminous galaxies have a steeper correlation function, and are thus more centrally concentrated in halos than the underlying dark matter. Lower luminosity galaxies, however, have a density profile that is consistent with that of dark matter. In order to see if this trend continues to higher redshift, we also measure the projected correlation function of SDSS-III BOSS CMASS galaxies on similar scales.

457.14 – Tilted Infall Regions?

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Recently, a thin plane of co-orbiting satellite galaxies was discovered around M31 (Ibata et al. 2013). Could there be similar unexpected flows on a larger scale, around galaxy clusters? In redshift space, infall regions with rotational flow distort into tilted artifacts. Transverse motion relative to the observer also causes a tilt. Are there galaxy clusters with structure that looks like this? In a recent exploratory study (Abdullah, Praton, Ali 2013), we show that some galaxy clusters do resemble tilted infall artifacts. The characteristic shape is obscured if the structure is axially convolved but clear when it is sliced, and can be fit by a spherical infall model (SIM) that is tilted by transverse motion or rotational flow. Tilted SIMs could therefore be a useful tool for roughly analyzing possible flows. We present a method for fitting tilted SIM envelopes and show how to use the tilt and width-to-length ratio of the envelope to estimate the possible velocity causing the tilt and also the observer's possible radial motion towards the cluster, if the structure is indeed an infall artifact. It is not clear if current cosmological n-body simulations can explain the galaxy clusters whose structure looks like a tilted infall artifact, since clusters in lambda-cdm simulations usually show little infall distortion. We found one similar shape in the outputs we examined. This n-body structure is not a result of velocity distortion and is mostly real (a pseudo-artifact). However, the velocity field of the nearest tilted galaxy cluster (Virgo) resembles a tilted SIM and not the pseudo-artifact. References Ibata, R.A. et al. 2013, Nature, 493, 62 Abdullah, M.H., Praton, E.A., & Ali, G.B. 2013, MNRAS, 434, 1989

457.15 – Faster, Better, Cheaper N-Body with Abacus

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We introduce Abacus, a cosmological N-body code based on a novel gravity solver. Abacus can obtain machine precision force accuracy at significantly greater speeds than any other currently available N-body code. This speed lets us run large-scale cosmological simulations on a single $8000 workstation built with commodity hardware. We present the results of a 4096^3 particle cosmological simulation, and examine the shift of the BAO acoustic scale bias as a first science application.

457.16 – Kinematic Morphology of Large-scale Structure: Evolution from Potential to Rotational Flow

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As an alternative way of describing the cosmological velocity field, we discuss the evolution of rotational invariants constructed from the velocity gradient tensor. Compared with the traditional divergence-vorticity decomposition, these invariants, defined as coefficients of characteristic equation of the velocity gradient tensor, enable a complete classification of all possible flow patterns in the dark-matter comoving frame, including both potential and vortical flows. Before shell-crossing, different categories of potential flow are highly associated with cosmic web structure, because of the coherent evolution of density and velocity. This correspondence is even preserved at some level when vorticity is generated after shell-crossing. The evolution from the potential to vortical flow can be traced continuously by these invariants. With the help of this tool, we show that the vorticity is generated in a particular way that is highly correlated with the large-scale structure. This includes a distinct spatial distribution and different types of alignment between cosmic web and vorticity direction for various vortical flows. Incorporating shell-crossing into closed dynamical systems is highly non-trivial, but we propose a possible statistical explanation for some of these phenomena relating to the internal structure of the three-dimensional

invariants space.

457.17 – A Large number of fast cosmological simulations

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Mock galaxy catalogs are essential tools to analyze large-scale structure data. Many independent realizations of mock catalogs are necessary to evaluate the uncertainties in the measurements. We perform 3600 cosmological simulations for the WiggleZ Dark Energy Survey to obtain the new improved Baron Acoustic Oscillation (BAO) cosmic distance measurements using the density field "reconstruction" technique. We use 1296^3 particles in a periodic box of 600/h Mpc on a side, which is the minimum requirement from the survey volume and observed galaxies. In order to perform such large number of simulations, we developed a parallel code using the COmoving Lagrangian Acceleration (COLA) method, which can simulate cosmological large-scale structure reasonably well with only 10 time steps. Our simulation is more than 100 times faster than conventional N-body simulations; one COLA simulation takes only 15 minutes with 216 computing cores. We have completed the 3600 simulations with a reasonable computation time of 200k core hours. We also present the results of the revised WiggleZ BAO distance measurement, which are significantly improved by the reconstruction technique.

457.18 – Dark Matter Halo Clustering in the LasDamas Simulations

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We use multiple runs of the Consuelo box of the LasDamas λCDM Cosmological simulations to investigate the clustering of distinct dark matter halos of at least 18.7×10^{10} M_{sun}/h in mass. This investigation is accomplished by examining how different correlation functions depend on different halo parameters. We primarily study the rank-marked correlation function, a type of two point auto-correlation function with pairs weighted by a product of ranks of different halo parameters: mass, v-max, spin, etc. This allows us to present an ordering of halo parameters with peak v-max as the most important factor governing the clustering of halos. Furthermore, this interpretation of the rank-marked correlation function is corroborated by less ambiguous or better understood tests including a simple test involving the difference in the two point auto-correlation function for halos in bins of the parameter being studied and more traditional assembly bias tests.

458 – Intergalactic Medium, QSO Absorption Line Systems Poster Session

Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

458.01 – High-Metallicity Outflows from QSOs: A Homogeneous Survey of Associated OVI Absorption with the Cosmic Origins Spectrograph

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We present the results of a search for ultraviolet absorption line spectra toward 69 quasars at 0.139 < z < 0.746 detected with the OVI λλ1032, 1038 Å doublet associated with the QSO host galaxy [i.e., with z(abs) ~ z(QSO)], drawn from the COS-Halos and COS-Dwarfs surveys. We find 63 absorption systems detected in the OVI doublet lines, where 31 of these absorbers show evidence for partial covering of the background quasar, suggesting that these absorbers are located very close to the central quasar. We characterize the parameters of our associated absorbing systems using CLOUDY ionization code, finding a median metallicity of [Z/H] = 0.3 and ionization parameter of U = -1.2. These metallicities are very high compared to studies of intervening OVI absorption systems, however, our results are consistent with expected conditions in absorbing systems undergoing enhanced radiation fields in the proximity of a central quasar. Because OVI is a fundamental tracer of galactic flows, this study provides information on the feedback processes that may be occurring between these outflows and galactic evolution.

458.02 – Constraining the Properties of OVI in the 0.4<z<1.0 Circumgalactic Medium

Ben Rosenwasser[1], Sowgat Muzahid[1], Jackson Norris[1], Jane C. Charlton[1], Paola Rodriguez Hidalgo[1,7], Bart P. Wakker[2], Anand Narayanan[3], Toru Misawa[4], Christopher W. Churchill[6], Nigel Mathes[6], Nikki Nielsen[6], Rajib Ganguly[5]

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The Circumgalactic Medium (CGM), the interface between galactic halos and the intergalactic medium, traces the evolution of gas flows into and out of galaxies. The study of the CGM provides important insight into the physical processes and evolution of galaxies. We can probe the tenuous CGM by studying intervening absorption lines in the spectra of quasars. Analyzing diagnostic lines that span a range of ionization levels (MgII, CII, SiIV, CIV, OVI) reveals the nature of these unilluminated environments. Studying the highly-ionized OVI ion is important for understanding the lowest density region of the CGM. We present a study of the absorption properties of ten intermediate redshift (0.4 < z < 1.0) MgII absorbers for which high resolution absorption profiles are available for low, intermediate, and high ionization metal-line transitions, as well as for HI. OVI is detected in six of the systems. We have carried out CLOUDY photoionization modeling of each of the systems to constrain the metallicities and infer ionization conditions for low and high ionization gas phases. We find varying, complex relationships between the mid- and high-ionization ions, namely SiIV, CIV, and OVI. OVI is not detected for a weak MgII absorber nor for a satellite around a strong MgII absorber, which may suggest these systems are not analogs of Milky Way HVCs. Our study helps elucidate the physical conditions of OVI absorption in a redshift range that has previously been, to a large extent, unobserved.

458.03 – Probing Quasar Winds Using Intrinsic Narrow Absorption Lines

Christopher S. Culliton[1], Jane C. Charlton[1], Michael Eracleous[1], Toru Misawa[2]

1. Pennsylvania State University, University Park, PA, United States. 2. Shinshu University, Matsumoto, Nagano, Japan.

We use the spectra of 73 quasars (1.5<z<5) from the VLT UVES archive to study and catalog narrow absorption lines (NALs) that are physically associated with (intrinsic to) the quasars. We study these NALs in order to better understand the characteristics of the NALs and their relations to the host quasar. We identify 410 NAL systems containing C IV, N V, and/or Si IV doublets. Based on the assumption that only systems intrinsic to the quasar can exhibit partial coverage of the background source(s), we identify 39 reliably intrinsic NAL systems, as well as 12 systems that are potentially intrinsic. The minimum fraction of quasars with at least one intrinsic NAL system is shown to be 41%. We identify intrinsic NALs with a wide range of properties, including ejection velocity, coverage fraction, and ionization level. There is a continuum of properties, rather than discrete families, ranging from partially covered CIV systems with black Lyman alpha and with a separate low ionization gas phase to partially covered NV systems with partially covered Lyman alpha and without detected

low ionization gas. Even more highly ionized associated and intrinsic absorption systems (OVI, NeVIII, and MgX doublets) have been presented in separate studies (Ganguly et al. 2013; Muzahid et al. 2012). We also use the properties of the NALs in conjunction with recent models of accretion disk winds that predict the origins of the absorbing gas in order to determine the model that best characterizes our sample. Additionally, we construct a toy model describing the spatial distributions, geometries, and varied ionization structures of intrinsic NALs.

458.04 – Evolution in the Frequency of Heavy Element Absorbers Approaching the Epoch of Reionization

Robert A. Simcoe[1], Kathy Cooksey[1, 2], Peter Sullivan[1], Thomas Cooper[1], Bram Venemans[3], Gisella deRosa[4]

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This contribution will summarize recent observational results on the high-redshift intergalactic and circumgalactic media from spectroscopy of Lya and metal lines between z~3 and z~7. A particular emphasis will be given to searches for heavy element absorption in the infrared spectra of newly-discovered QSOs at z > 6.5.

458.05 – High-z QSO Absorption Systems: Metal-Poor Cold Flows and Mg II Absorber Host Galaxies

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Cosmological simulations have suggested a new model for gas accretion in young galaxies, in which baryons flow into the star-forming disk along filamentary streams without shock heating at the dark matter halo virial radius. Observationally, these cold flows manifest as Lyman Limit Systems with low heavy element abundances. To search for cold flows in the early Universe, we have obtained echellette-resolution spectra of an HI-selected sample of LLS at z>3.5 from the Sloan Digital Sky Survey. The sightlines were selected to exhibit no heavy element absorption at the resolution afforded by SDSS, and the higher resolution data provides metallicity measurements precise enough to determine if they exhibit cold flow accretion characteristics. In a parallel program, we use the Magellan Telescopes and HST/WFC-3 to investigate the connection between Mg II absorbers and proximate galaxies at z~3, extending fruitful studies of the circumgalactic medium to larger redshift.

458.06 – The Varied Conditions of Low Redshift Weak MgII Absorbers

Gloria Fonseca[1], Benjamin Rosenwasser[1], Amber Roberts[1], Alex Koury[1], Christopher S. Culliton[1], Sowgat Muzahid[1], Anand Narayanan[2], Paola Rodriguez Hidalgo[3], Jane C. Charlton[1]

1. The Pennsylvania State University, University Park, PA, United States. 2. University of Michigan, Ann Arbor, MI, United States. 3. York University, York, York, United Kingdom.

Quasar absorption lines allow us to study parts of the universe that are otherwise not visible to us. Weak MgII absorbers, defined to be those with rest frame equivalent widths Wr(2796) < 0.30 Å, trace the processes that link galaxies and the intergalactic medium. These absorbers usually have metallicities at solar or super solar values, despite being relatively far (>50kpc) from the luminous galaxies that are normally associated with such high metallicities. Further study of these absorbers will give insight to the origin of this high metallicity material. A previous survey of weak MgII absorbers at redshifts 0 < z < 0.3 (Narayanan et. al 2005), searched 20 quasar lines of sight using data from the Space Telescope Imaging Spectrograph (STIS). The survey used SiII(1260) and CII(1335) as analogs for MgII absorption. Narayanan et. al found 6 weak MgII absorber analogs over a redshift path length of ~5.4. At low redshift, the weak MgII absorbers are a varied population, with some arising from single phase kpc-scale structures, and others from two-phase structure with a small high-density MgII cloud surrounded by a larger (order of kpc) lower-density region responsible for the CIV absorption. We conducted a survey of ~ 400 quasars observed with the Cosmic Origins Spectrograph on board the Hubble Space Telescope, again using SiII(1260) and CII(1335) as tracers of MgII absorption for z<0.3. We find 35 analogs to weak MgII absorbers in our sample, giving a redshift path density consistent with Narayanan et. al. Our larger sample allows us to build statistics and isolate three classes of absorbers: 1) Weak low ionization absorbers with detected CIV that require two phases; 2) Weak low ionization absorbers with detected CIV that are consistent with a single phase; 3) Weak low ionization absorbers with no detected CIV. The latter tend to be the weakest, and consistently have solar or super solar metallicities. Also notable are those absorbers with no detected OVI,which could then arise in a single higher density phase.

458.07 – PROBING THE LARGE SCALE OUTFLOWS OF THE DARK SIDE OF THE LMC BY PIERCING THROUGH THE DISK

Kathleen A. Barger[1], J. C. Howk[1], Nicolas Lehner[1]
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Galaxy interactions have greatly disturbed the Large Magellanic Cloud, triggering intense star formation throughout this galaxy. Evidence for a widespread gaseous outflow driven by this star formation has been seen in previous absorption-line studies toward stars in the disk, with only a small fraction of the sight lines showing gas at velocities consistent with inflow. However, there was some ambiguity in this interpretation since these absorption line studies toward LMC disk stars were sensitive only to the near side of the LMC. We provide compelling evidence that the LMC drives a global, large scale wind that permeates from its entire disk based on Hubble Space Telescope/COS UV absorption line observations of a quasar sight line that probes both the near and far side of the disk in a relatively quiescent region of this galaxy. Comparison of this sight line with our HST/STIS observations toward a star projected ~100 pc away allows us to break the ambiguities in interpreting the velocities of the absorption. The outflowing gas is flowing outward at speeds of 100 km/s. At these velocities, much of this ionized gas will escape from the galaxy. K. A. Barger is supported through the NSF Astronomy and Astrophysical Postdoctoral Fellowship award AST 1203059.

458.08 – Properties of Two Strong MgII Absorbers Towards Q0454-220

Jackson Norris[1], Jane C. Charlton[1], Sowgat Muzahid[1], Ben Rosenwasser[1]
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We present the physical properties of two strong MgII systems at z=0.4744 and z=0.4833 toward the quasar Q0454-220. A Keck/HIRES spectrum (resolution R=45,000) covers prominent low ionization features: MgII, FeII, CaII, and MgI. A HST/COS spectrum (R~17,000) covers the OVI and NV features. A HST/STIS spectrum (R=30,000) covers the CIV and SiIV doublets. A HST/FOS spectrum (R=1,300) and HST/COS spectrum (R~17,000) cover the Lyman series lines and Lyman break region for hydrogen. The z=0.4744 system is a sub-DLA system, and the z=0.4833 system also produces a full Lyman limit break. Beginning with Voigt profile fits to the highest resolution data, we modeled these systems using the Cloudy photoionization code. The incident radiation is assumed to be a Haardt-Madau extragalactic background spectrum due to quasars and star-forming galaxies. We derive ranges of ionization parameters, number densities, sizes, temperatures, and metallicities for the absorbing clouds.

458.09 – Investigating TeV Gamma Ray Propagation: an Integration Approach along Blazar/Absorber Sightlines to Establish Minimum Photon Densities

Julie Davis[1], Charles Danforth[1], Brian A. Keeney[1], John T. Stocke[1]
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The standard model for propagation of gamma rays from very high energy (VHE, E>100 GeV) blazars through the universe requires an understanding of the diffuse extragalactic background light (EBL). Due to photon-photon collision and pair production from gamma ray/infrared photon interaction in the intergalactic medium, we expect to see a redshift "horizon" beyond which gamma rays from these sources are no longer observable. Three TeV-bright blazars examined in this project pose a problem to the horizon hypothesis due to their substantial redshifts, requiring reevaluation of either the gamma-ray propagation model or the EBL model. This project establishes a minimum density of infrared photons and a potential lower limit on the EBL flux toward these high-z blazars by integrating and summing flux contributions from intervening galaxies within reasonable impact parameters of the blazar sight lines. Galaxies along the lines of sight and their flux contributions are inferred from from measured HI (Lyman alpha forest) and metal-ion absorbers seen in far-UV spectra of PKS1424+240 and 3C66A (HST/COS) and 3C279 (HST/FOS).

458.10 – Intergalactic Extinction

Bradley Mills[1], Aigen Li[1]
1. University of Missouri, Columbia, MO, United States.

The apparent systematic dimming of high-redshift Type Ia supernovae has been interpreted as evidence of acceleration in the cosmological expansion of the universe. An alternative hypothesis to this interpretation is the gray extinction of intergalactic dust. Based on the intergalactic abundances of the dust-forming elements (C/H, O/H, Si/H, and Fe/H), we place upper limits on the intergalactic extinction, with various dust species and mixtures taken into account.

458.11 – Understanding Low-Redshift Quasar Outflows Using Intrinsic NV Absorption Lines.

Amber Roberts[1], Culliton Christopher[1], Jeffery A. Derseweh[2], Sowgat Muzahid[1], Jane C. Charlton[1], Rajib Ganguly[2]
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Flint, Flint, PA, United States.

Quasar outflows are important for understanding the accretion and growth processes of the central black hole. Furthermore, outflows potentially have a role in providing feedback to the galaxy, and halting star formation and infall of gas. The geometry and density of these outflows remain unknown, especially as a function of ionization and velocity. We aim to tackle this by using ultraviolet spectra from the Hubble Space Telescope Cosmic Origins Spectrograph archive to locate intrinsic NV absorption systems. So far our survey has uncovered 58 NV systems in the 450 low-redshift quasars. Absorption-line systems with velocities |?v| ≤ 5000 km s1 are considered associated with the quasar and our survey results show nearly all systems selected by the NV ion are associated. The Lyα absorption associated with the NV doublet is saturated, but non-black, indicating partial covering. With the use of partial coverage analysis we show that nearly all the associated NV systems are intrinsic to the background QSO. We also consider the incidence of intrinsic absorbers as a function of quasar properties (optical, radio and X-ray). With the use of a wide range of diagnostic lines to constrain the physical conditions of the absorbers, this survey provides the largest set yet of intrinsic absorbers with systematic distance constraints. We will further consider potential ionization structures and geometries to explain the formation of these systems.

458.12 – A Comparison of the Circumgalactic Medium of Present-Day Dwarf and Milky Way Galaxies using Absorption Line Analysis through Hydrodynamic Cosmological Simulations

Jacob R. Vander Vliet[1], Christopher W. Churchill[1], Sebastian Trujillo-Gomez[1], Elizabeth S. Klimek[1], Anatoly A. Klypin[1]

1. New Mexico State University, Las Cruces, NM, United States.

Dwarf galaxies are predicted to have a unique halo structure. They experience the same feedback as more massive galaxies but lack the strong gravitational potential. The structure and composition of gas around dwarfs should be different than for gas around massive galaxies. These differences would show up in quasar absorption spectra. We test this idea by examining mock quasar spectra of the circumgalactic medium of two simulated dwarf galaxies to determine the extent of their metal halos at redshift zero. The galaxies are from a cosmological zoom-in simulation using Eulerian Gasdynamics plus N-body Adaptive Refinement Tree (ART) code. Both galaxies have the same initial conditions but are simulated with different physical conditions. One uses only supernova feedback while the other adds in radiative pressure and an increase in star formation efficiency to recreate the correct stellar properties. We measure the absorption lines of several ions including MgII, CIV, OVI, SiIV, and Ly beta and compare the covering fraction, equivalent width distribution and the velocity distribution for both simulations. These are then compared to more massive halos to explore how the galaxy's mass affects their CGM structure.

458.13 – A Statistical Study of Mg II Absorption Selected Galaxies in the SDSS at z~0.4

Brittney Curtis[1], Britt Lundgren[2]

1. Ohio State University, Columbus, OH, United States. 2. University of Wisconsin- Madison, Madison, WI, United States.

The spectra of distant quasars frequently exhibit absorption features from singly-ionized magnesium (Mg II), which are understood to trace gas outflow and accretion processes in foreground galaxies. Host galaxies of the Mg II absorbing gas are difficult to detect because they are often faint and have small angular separation from the bright background quasar. We have undertaken a statistical study of low redshift (z~0.4) galaxies identified as potential Mg II absorption hosts which are visible in the Sloan Digital Sky Survey (SDSS). Using data from the SDSS DR7, we compiled a census of ~3200 photometrically-identified galaxies within a projected 150 kpc of an Mg II absorbing system. These potential Mg II absorption hosts were then compared to a control sample of galaxies in the foreground of quasars without absorption systems in the same redshift range. We report a positive detection of excess galaxies around the lines of sight to quasars with Mg II absorption systems, extending to ~90 kpc. We present the luminosity distribution of these excess galaxies and compare to previous, smaller studies from the literature. This work was partially supported by the National Science Foundation's REU program through NSF Award AST-1004881 to the University of Wisconsin-Madison.

459 – The NASA SMD Science Education and Public Outreach Forum
Poster Session – Exhibit Hall ABC – 09 Jan 2014 09:00 am to 02:00 pm

459.01 – The NASA SMD Science Education and Public Outreach Forums: Engaging Scientists in NASA Education and Public Outreach

Denise A. Smith[1], Laura Peticolas[2], Theresa Schwerin[3], Stephanie Shipp[4]
1. STScI, Baltimore, MD, United States. 2. UC-Berkeley, Berkeley, CA, United States. 3. IGES, Arlington, VA, United States. 4. LPI, Houston, TX, United States.

The NASA Science Mission Directorate (SMD) Education and Public Outreach (E/PO) program provides a direct return on the public's investment in NASA's science missions and research programs through a comprehensive suite of educational resources and opportunities for students, educators, and the public. Four Science Education and Public Outreach Forums work with SMD-funded missions, research programs, and grantees to organize individual E/PO activities into a coordinated, effective, and efficient nationwide effort, with easy entry points for scientists, educators, and the public. We outline the Forums' role in 1) facilitating communication and collaboration among SMD E/PO programs, scientists, and educators; 2) supporting utilization of best practices and educational research; 3) creating clear paths of involvement for scientists interested in SMD E/PO; and, 4) enabling efficient and effective use of NASA content and education products. Our work includes a cross-Forum collaboration to inventory existing SMD education materials; identify and analyze gaps; and interconnect and organize materials in an accessible manner for multiple audiences. The result is NASAWavelength.org, a one-stop-shop for all NASA SMD education products, including tools to help users identify resources based upon their needs and national education standards. The Forums have also collaborated with the SMD E/PO community to provide a central point of access to metrics, evaluation findings, and impacts for SMD-funded E/PO programs (http://smdepo.org/page/5324). We also present opportunities for the astronomy community to participate in collaborations supporting NASA SMD efforts in the K – 12 Formal Education, Informal Education and Outreach, Higher Education and Research Scientist communities. See Bartolone et al., Lawton et al., Meinke et al., and Buxner et al. (this conference), respectively, to learn about Forum resources and opportunities specific to each of these communities.

459.02 – Engaging Scientists in NASA Education and Public Outreach: Tools for Scientist Engagement

Sanlyn Buxner[1], Bonnie K. Meinke[2], Brooke Hsu[3], Christine Shupla[3], Jennifer A. Grier[1]
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Contributing teams: SMD E/PO Community

The NASA Science Education and Public Outreach Forums support the NASA Science Mission Directorate (SMD) and its education and public outreach (E/PO) community through a coordinated effort to enhance the coherence and efficiency of SMD-funded E/PO programs. The Forums foster collaboration between scientists with content expertise and educators with pedagogy expertise. We present tools and resources to support astronomers' engagement in E/PO efforts. Among the tools designed specifically for scientists are a series of one-page E/PO-engagement Tips and Tricks guides, a sampler of electromagnetic-spectrum-related activities, and NASA SMD Scientist Speaker's Bureau (http://www.lpi.usra.edu/education /speaker). Scientists can also locate resources for interacting with diverse audiences through a number of online clearinghouses, including: NASA Wavelength, a digital collection of peer-reviewed Earth and space science resources for educators of all levels (http://nasawavelength.org), and EarthSpace (http://www.lpi.usra.edu/earthspace), a community website where faculty can find and share teaching resources for the undergraduate Earth and space sciences classroom. Learn more about the opportunities to become involved in E/PO and to share your science with students, educators, and the general public at http://smdepo.org.

459.03 – Engaging Scientists in NASA Education and Public Outreach: Informal Science Education and Outreach

Brandon L. Lawton[1], Denise A. Smith[1], Lindsay Bartolone[2], Bonnie K. Meinke[1]
1. STScI, Baltimore, MD, United States. 2. Adler Planetarium, Chicago, IL, United States.
Contributing teams: Universe Discovery Guides Collaborative, NASAScience4Girls Collaborative, SEPOF Informal Education Working Group, SMD E/PO Community

The NASA Science Education and Public Outreach Forums support the NASA Science Mission Directorate (SMD) and its education and public outreach (E/PO) community through a coordinated effort to enhance the coherence and efficiency of SMD-funded E/PO programs. The Forums foster collaboration between scientists with content expertise and educators with pedagogy expertise. We present opportunities for the astronomy community to participate in collaborations supporting the NASA SMD efforts in the Informal Science Education and Outreach communities. Members of the Informal Science Education and Outreach communities include museum/science center/planetarium professionals, librarians, park rangers, amateur astronomers, and other out-of-school-time educators. The Forums' efforts for the Informal Science Education and

Outreach communities include a literature review, appraisal of informal educators' needs, coordination of audience-based NASA resources and opportunities, and professional development. Learn how to join in our collaborative efforts to reach the informal science education and outreach communities based upon mutual needs and interests.

459.04 – Engaging Scientists in NASA Education and Public Outreach: K - 12 Formal Education

Lindsay Bartolone[1], Denise A. Smith[2], Bonnie Eisenhamer[2], Brandon L. Lawton[2]
1. Adler Planetarium, Chicago, IL, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States.
Contributing teams: Multiwavelength Universe Professional Development Collaborative, Use of NASA Data Collaborative, SEPOF K-12 Formal Education Working Group, SMD E/PO Community

The NASA Science Education and Public Outreach Forums support the NASA Science Mission Directorate (SMD) and its education and public outreach (E/PO) community through a coordinated effort to enhance the coherence and efficiency of SMD-funded E/PO programs. The Forums foster collaboration between scientists with content expertise and educators with pedagogy expertise. We present opportunities for the astronomy community to participate in collaborations supporting the NASA SMD efforts in the K – 12 Formal Education community. Members of the K – 12 Formal Education community include classroom educators, homeschool educators, students, and curriculum developers. The Forums' efforts for the K – 12 Formal Education community include a literature review, appraisal of educators' needs, coordination of audience-based NASA resources and opportunities, professional development, and support with the Next Generation Science Standards. Learn how to join in our collaborative efforts to support the K – 12 Formal Education community based upon mutual needs and interests.

459.05 – Engaging Scientists in NASA Education and Public Outreach: Higher Education

Bonnie K. Meinke[1], Denise A. Smith[1], Gregory R. Schultz[2], Brandon L. Lawton[1], Luciana Bianchi[3], William P. Blair[3], Sanlyn Buxner[4]
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Contributing teams: SEPOF Higher Education Working Group, SMD E/PO Community

The NASA Science Education and Public Outreach Forums support the NASA Science Mission Directorate (SMD) and its education and public outreach (E/PO) community through a coordinated effort to enhance the coherence and efficiency of SMD-funded E/PO programs. The Forums foster collaboration between scientists with content expertise and educators with pedagogy expertise. We present opportunities for the astronomy community to participate in collaborations supporting the NASA SMD efforts in the Higher Education community. Members of the Higher Education community include instructors, faculty, and students at community colleges and four-year colleges/universities. The Forums' efforts for the Higher Education community include a literature review, appraisal of instructors' needs, coordination of audience-based NASA resources and opportunities, and classroom support materials. Learn how to join in our collaborative efforts to support the Higher Education community based upon mutual needs and interests.

401 – A Melange of Circumstellar and Stellar Presentations

Oral Session – Maryland Ballroom B – 09 Jan 2014 10:00 am to 11:30 am

401.01 – Orbit evolution of disk-embedded masses: Directly observed in Saturn's rings

Matthew S. Tiscareno[1], Allegra E. Moran[1]
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Disk-embedded masses are thought to exist and evolve in many astrophysical contexts, including protoplanetary and protosatellite disks, stellar debris disks, and galaxies. The only known "ground truth" for these theorized objects is found in Saturn's rings. The "propeller" moons within Saturn's rings are the first objects ever to have their orbits tracked while embedded in a disk, rather than moving through empty space (Tiscareno etal. 2010, ApJL). The embedded masses are not seen directly; rather, their locations are inferred by means of the propeller-shaped disturbances they create in the surrounding ring material (Tiscareno etal. 2006, Nature). Their observed orbits are primarily Keplerian, but with clear excursions in longitude on the order of +-0.15 degrees longitude for the largest and best-studied example, and +-several degrees longitude for others. Most theories that have been proposed to explain the non-Keplerian motion of propeller moons rely on gravitational and/or collisional interactions between the moon and the surrounding disk, and thus hold out the prospect for directly observing processes that are important in other astrophysical disk systems. The different models make different predictions, and future data will likely distinguish among them. The Cassini spacecraft, currently orbiting Saturn, is monitoring the propeller moons whenever possible. We will report the latest results of that observing campaign.

401.02 – Exocomet Gas: Now You See It, Now You Don't

Sharon L. Montgomery[1], Barry Welsh[2], Rosine Lallement[3], Bryon W. Timbs[1]
1. Clarion University, Clarion, PA, United States. 2. Space Science Laboratory, University of California Berkeley, Berkeley, CA, United States. 3. GEPI - Paris Observatory, Meudon, France.

We present high spectral resolution observations of circumstellar gas present in the disks surrounding young (< 50 Myr old) A-type stars. By monitoring absorption due to the CaII K (3933Å), NaI D (5890Å) and CaII IR Triplet (8542Å) lines on a nightly basis we have detected significant variations in both their strength and velocity structure. This type of behavior, first seen in the exoplanet-harboring Beta Pictoris system, is thought to be due to the evaporation of gas by small planetesimals ('exocomets') on their grazing approach to the central star. In particular, we trace the evolution of absorption features that appear and disappear in the spectra of the A3V star 2 And (HD 217782) and the A0V star 5 Vul (HD 182919) on time-scales of hours, days and months. These observations represent the first simultaneous observations of the three afore-mentioned absorption lines in systems containing circumstellar gas and dust disks.

401.03 – Finding the Faintest Exozodi and Asteroid Belt Analogs in WISE

Rahul Patel[1], Stanimir Metchev[2, 1], Aren Heinze[3]
1. SUNY Stony Brook, East Setauket, NY, United States. 2. University of Western Ontario, London, ON, Canada. 3. Stony Brook University, Stony Brook, NY, United States.

The presence of circumstellar dust in the terrestrial planet zone and asteroid belt regions of stars can be ascertained from the excess flux from main sequence stars in the near to mid-infrared wavelengths. Finding dust in these regions around stars is significant as it traces material related to terrestrial planet formation. In this study, we use the WISE All-Sky Survey data to detect circumstellar debris disks at the 12 and 22 μm bandpasses (W3 and W4, respectively). We present the detection of a sample of over 220 exozodi and asteroid belt analog candidates, 74% of which are brand new detections all at confidence levels >95%. This was done by cross-matching Hipparcos main-sequence stars with the WISE All-Sky Data Release for stars within 75 pc and outside the galactic plane (|b|>5°) and then seeking color excesses at W3 and W4. In addition to applying the standard WISE photometric flags and filters to remove contaminants from our sample, we also improved our selection techniques by correcting for previously unknown systematic behavior in the WISE photometry. Our debris disk candidates are reliable detections as well as unprecedentedly faint, due in large part to these improved selection techniques.

401.04 – CHASING DISK DISPERSAL INDICATORS: THE ORIGIN OF THE [OI] LOW-VELOCITY COMPONENT FROM YOUNG STELLAR OBJECTS

Elisabetta Rigliaco[1], Ilaria Pascucci[1], Uma Gorti[2, 3], Suzan Edwards[4], David J. Hollenbach[3]
1. University of Arizona, Department of Planetary Science, Tucson, AZ, United States. 2. NASA Ames Research Center, Mountain View, CA, United States. 3. SETI Institute, Mountain View, CA, United States. 4. Smith College, Northampton, MA, United States.

The formation time, masses, and location of planets are strongly impacted by the physical mechanisms that disperse protoplanetary disks and the timescale over which protoplanetary material is cleared out. Accretion of matter onto the

central star, protostellar winds/jets, magnetic disk winds, and photoevaporative winds operate concurrently. Hence, disentangling their relative contribution to disk dispersal requires identifying diagnostics that trace different star-disk environments. Here, I will discuss the analysis the low velocity component (LVC) of the Oxygen optical forbidden lines, which is found to be blueshifted by a few km/s with respect to the stellar velocity. We find that the [OI] LVC profiles are different from those of other lines tracing disk and photoevaporative winds ([NeII] at 12.81μm and CO at 4.7μm), pointing to different origins for these gas lines. The analysis of the [OI] LVC, and the comparison with the stellar properties favor an origin of the [OI] LVC in a region where OH is photodissociated by stellar FUV photons and argue against thermal emission from an X-ray-heated layer. Detailed modeling of two spectra with the highest S/N and resolution shows that there are two components within the LVC: a broad, centrally peaked component that can be attributed to gas arising in a warm disk surface in Keplerian rotation, and a narrow component that may arise in a cool (<1,000 K) molecular wind.

401.05 – Analyzing the Shock Heating Rate in O-Star Winds

Zequn Li[1], David H. Cohen[1]
1. Swarthmore College, Swarthmore, PA, United States.

What is the shock strength distribution in O star winds? Answering this question could provide important observational constraints on hydrodynamic simulations of the line-driven instability (LDI). Traditional emission-measure based approaches to characterizing the shocked wind plasma temperature distribution entangle the desired information about shock heating with the effects of cooling. Our new approach is to connect the X-ray emission line spectra with the radiative cooling of the shocked gas in order to isolate information about the shock heating. Focusing on six stars which lack or have distant binary companions, we calculate the probability that a parcel of gas in the wind reaches a given temperature based on the measured X-ray line strength distribution. We compare our derived shock heating distributions to numerical simulations of the LDI.

402 – AGN Across Cosmic Time
Oral Session – National Harbor 11 – 09 Jan 2014 10:00 am to 11:30 am

402.01 – Half-Megasecond Spectral Imaging of the Galactic Winds in Mrk 231

Stacy H. Teng[1], Sylvain Veilleux[2], David Rupke[3], Roberto Maiolino[4], Eckhard Sturm[5]
1. NASA/GSFC, Greenbelt, MD, United States. 2. University of Maryland, College Park, MD, United States. 3. Rhodes College, Memphis, TN, United States. 4. University of Cambridge, Cambridge, United Kingdom. 5. MPE, Garching, Germany.

In the past few years, Mrk 231 has become the best laboratory to study quasar feedback in action due to the galaxy's proximity. Recent observations have revealed that Mrk 231 is host to a powerful, spatially resolved wind with velocities in excess of -1000 km/s. This wide-angled outflow, in both neutral and molecular phases, extends over a few kpc and is thought to be a quasar wind. This may be evidence that quasar mechanical feedback is important and can transform gas-rich mergers such as Mrk 231 into red and dead galaxies. We present the results from our analysis of 500+ ks of Chandra ACIS-S new and archival data on the X-ray faint nebula surrounding the quasar.

402.02 – Investigating the AGN-Star formation Connection in the Local Universe

Stephanie M. LaMassa[1], Timothy M. Heckman[2], Andrew Ptak[3], C. M. Urry[1]
1. Yale University, New Haven, CT, United States. 2. The Johns Hopkins University, Baltimore, MD, United States. 3. NASA Goddard Space Flight Center, Greenbelt, MD, United States.

Using a sample of ~28,000 local obscured AGN from the Sloan Digital Sky Survey, we investigate the connection between star formation and AGN activity over a range of radial scales. We use the extinction corrected [OIII] 5007 Angstrom luminosity as a proxy of AGN activity and star formation rates derived from the MPA-JHU value added catalog, both of which are measured through the 3" SDS aperture. We construct matched samples of galaxies in redshift and map out the radial distribution of star formation as a function of AGN luminosity, where the projected aperture size covers increasing amounts of the host galaxy with increasing redshift. The star formation rate becomes more compact with increasing AGN luminosity, suggesting that the star formation rate associated with black hole fueling dominates over omnipresent host galaxy star formation at relatively high AGN luminosities. Theoretical models that link AGN and star formation activity at the circumnuclear, rather than galactic, scale are therefore favored by our results.

402.03 – A ~3.8 hour Periodicity from an Ultrasoft Active Galaxy

Dacheng Lin[1], Jimmy Irwin[1], Olivier Godet[2], Natalie Webb[2], Didier Barret[2]
1. University of Alabama, Tuscaloosa, AL, United States. 2. IRAP, Toulouse, France.

Very few galactic nuclei are found to show significant X-ray quasi-periodic oscillations (QPOs). After carefully modeling the noise continuum, we find that the ~3.8 hr QPO in the ultrasoft active galactic nucleus (AGN) candidate 2XMM J123103.2+110648 was significantly detected (~5sigma) in two XMM-Newton observations in 2005, but not in the one in 2003. The QPO rms is very high and increases from ~25% in 0.2-0.5 keV to ~50% in 1-2 keV. The QPO probably corresponds to the low-frequency type in Galactic black hole X-ray binaries, considering its large rms and the probably low mass (~10^5 solar mass) of the black hole in the nucleus. We also fit the soft X-ray spectra from the three XMM-Newton observations and find that they can be described with either pure thermal disk emission or optically thick low-temperature Comptonization. We see no clear X-ray emission from the two Swift observations in 2013, indicating lower source fluxes than those in XMM-Newton observations.

402.04D – Exploring Quasar SEDs as a Function of Black Hole Properties

Coleman M. Krawczyk[1], Gordon T. Richards[1]
1. Drexel University, Philadelphia, PA, United States.

Using a sample of ~102, 000 quasars from the Sloan Digital Sky Survey's (SDSS) 7th data release, cross-matched to Spitzer and WISE in the mid-IR, 2MASS and UKIDSS in the near-IR, and GALEX in the UV, we explore how the shape of their spectral energy distributions (SEDs) changes based on the properties of the central black hole. In particular we look at the color trends of the SEDs as functions of both the central black hole mass (M_{BH}) and the Eddington ratio ($\lambda_{Edd} = L_{disk}/L_{Edd}$). We compare our observations to models which predict that quasars are redder for large values for M_{BH} and bluer for large values of λ_{Edd}. By combining the black hole masses with the shape of the SED we also place limits on the mass accretion rate for each quasars, where the exact value depends on the accretion disk model used. We acknowledge support from NASA grant NNX12AI49G.

402.05 – The AGN Census at Cosmic Noon: the Unbiased Galaxy-AGN Connection from Spatially Resolved Line Ratios

Jonathan R. Trump[1], W. N. Brandt[1], Benjamin J. Weiner[2], Stephanie Juneau[3]
1. Penn State, University Park, PA, United States. 2. University of Arizona, Tucson, AZ, United States. 3. CEA-Saclay, Gif-sur-Yvette, France.
Contributing teams: CANDELS, 3D-HST

I will present a "census" of active galactic nuclei (AGN) at the cosmic noon of 1<z<2.5, quantified as the fraction of AGN among host galaxies of different stellar mass, star formation rate, and morphology. Such a census is made possible through the unique spatial resolution of HST/WFC3 spectroscopy (from 3D-HST and AGHAST) and imaging (from CANDELS). I will demonstrate that spatially resolved line ratios enable AGN selection which is much less biased by host properties than X-ray, IR, or classical BPT selection. Beyond the simple AGN-galaxy occupation fraction, I will also reveal how AGN accretion is tied to host galaxy star formation, with little connection to stellar mass or morphology.

402.06 – Exploring black hole seed formation and early growth at z>6

Kevin Schawinski[1], Anna Weigel[1], Ezequiel Treister[3], C. M. Urry[2]
1. ETH Zurich, Zurich, Switzerland. 2. Yale University, New Haven, CT, United States. 3. Universidad de Concepcion, Concepcion, Chile.

We search the 4 Msec Chandra Deep Field South data for signs of X-ray emission from black hole growth in proto-galaxies. We use two approaches: we use stacking of X-ray data of known z=6-8 dropout galaxies to constrain the integrated X-ray emission due to black hole accretion; we also investigate detected X-ray sources and determine if they are high redshift (z>6) AGN. Our results place new observational constraints on seed formation mechanisms and pose challenges both to our understanding of the origin of black holes, and inform how future observational campaigns could be carried out.

403 – APOGEE - A Fresh View Into the Stellar Populations of the Milky Way

Special Session – National Harbor 3 – 09 Jan 2014 10:00 am to 11:30 am

Our understanding of the formation of the Milky Way Galaxy is on the verge of a revolution, with several massive surveys of the stellar populations of the Galaxy currently in operation, and others in design stage. At the cutting edge of that trend, the Apache Point Observatory Galactic Evolution Experiment (APOGEE), is collecting high resolution (R=23,000), high S/N (100/res. el.) for 100,000 mostly giant stars from all components of the Galaxy, from which accurate radial velocities and elemental abundances are being derived. As the world's only major high-resolution NIR survey of Galactic stars, APOGEE has unique power to probe the disk and bulge populations. Thus, APOGEE will make a transformational contribution in a range of scientific fronts, including abundance gradients in the Galactic disk, the metallicity distribution of the Galactic bulge, kinematic signatures of the Galactic bar and its interplay with the bulge and disk, as well as a number of fundamental astrophysical problems, including diffuse interstellar bands, the ages of field stars, the dynamical masses of eclipsing binaries, and the envelopes of Be stars. With the first APOGEE public data release (as part of SDSS-III DR10), and the publication of the first several science results, the time is ripe for a focused discussion of key APOGEE science and the future exploitation of the growing APOGEE data base. This Special Session will include a survey overview and a combination of invited and contributed talks and posters, highlighting the first important APOGEE science results.

403.01 – Status of the Apache Point Observatory Galactic Evolution Experiment (APOGEE)

Steven R. Majewski[1]
1. Univ. of Virginia, Charlottesville, VA, United States.
Contributing teams: The SDSS-III/APOGEE Collaboration

The Apache Point Observatory Galactic Evolution Experiment (APOGEE), one of the programs in Sloan Digital Sky Survey III (SDSS-III/APOGEE) is now in its third year of operations. APOGEE is producing a large catalog of high resolution (R~22,500), high quality (S/N > 100), infrared (H-band: 1.51-1.68 μm) spectra for stars throughout all stellar populations of the Milky Way, and including time series information via repeat visits to stars. Having already collected >350,000 spectra of >75,000 unique stars, APOGEE is making a variety of impactful discoveries, including the first detection of a high-velocity stellar population in the Milky Way's central bar, measurements of the Galactic rotation, chemical maps of the disk and bulge, and the discovery of rare stellar species. I will summarize the status of the APOGEE project and its successor, the dual-hemisphere APOGEE-2 project, and give an overview of science results generated by this large, detailed, spectroscopic survey of Milky Way stars.

403.02 – Chemical Cartography with APOGEE

Jon A. Holtzman[1], Michael R. Hayden[1], Jo Bovy[4], Steven Majewski[2], Jennifer Johnson[5], Gail Zasowski[5], Leo Girardi[9], Carlos Allende-Prieto[8], Ana Elia Garcia Perez[2], Szabolcs Meszaros[7], David L. Nidever[3], Ricardo P. Schiavon[10], Matthew D. Shetrone[6]
1. New Mexico State Univ., Las Cruces, NM, United States. 2. University of Virginia, Charlottesville, VA, United States. 3. University of Michigan, Ann Arbor, MI, United States. 4. Institute of Advanced Studies, Princeton, NJ, United States. 5. Ohio State University, Columbus, OH, United States. 6. McDonald Observatory, Fort Davis, TX, United States. 7. Indiana University, Bloomington, IN, United States. 8. IAC, Tenerife, Spain. 9. OAPD, Padova, Italy. 10. Liverpool John Moores, Liver, United Kingdom.

The SDSS-III APOGEE experiment is obtaining high-resolution near-IR spectra to provide measurements of stellar parameters and chemical abundances for stars in many different regions of the Galaxy. I will discuss initial results on the spatial variations of abundances derived from APOGEE data to date. In particular, I focus on mean metallicities in the Milky Way disk over a large range of Galactocentric radius (3<R<15) and distance from the Galactic midplane (|z|< 3kpc), and the metallicity gradients that are derived from these. Issues involving distance estimates and potential biases in the mean metallicities will also be discussed, as well as directions for extending this work.

403.03 – Mapping the Bulge Metallicity Distribution Function with APOGEE

Ana Elia Garcia Perez[1], Jennifer Johnson[2], Katia M. Cunha[3], Carlos Allende-Prieto[4], Matthew D. Shetrone[5], Steven R. Majewski[1], Ricardo P. Schiavon[6], Peter M. Frinchaboy[7], Michael R. Hayden[8], David L. Nidever[9], Annie Robin[10], Mathias Schultheis [11], Gail Zasowski[12]
1. University of Virginia, Charlottesville, VA, United States. 2. The Ohio State University, Columbus, OH, United States. 3. Observatorio Nacional, Rio de Janeiro, Rio de Janeiro, Brazil. 4. Instituto de

Astrofisica de Canarias, La Laguna, Tenerife, Spain. 5. McDonald Observatory, For Davis, TX, United States. 6. Texas Christian Univesity, Fort Worth, TX, United States. 7. New Mexico State University, Las Cruces, NM, United States. 8. University of Michigan, Ann Arbor, MI, United States. 9. Institut Utinam, Besancon, France. 10. University of Liverpool, Liverpool, Merseyside, United Kingdom. 11. Observatoire de la Cote d'Azur, Nice, France. 12. John Hopkins University, Baltimore, MD, United States.

The origin and formation of the Milky Way bulge remains poorly understood, in part because high quality observations of the bulge have generally been restricted to regions of low extinction. In the presence of dust, infrared observations confer a distinct advantage over those at optical wavelengths, and the advent of the Apache Point Observatory Galactic Evolution Experiment (APOGEE) enables us to exploit widely this advantage for the study of the kinematics and chemistry across the entire bulge, including high extinction fields near the Galactic plane. Present APOGEE coverage includes Northern Hemisphere-accessible bulge fields spanning a 20 degree radius from the Galactic Center. The analysis of the high quality (R ~ 22,500 and a typical S/N > 100) stellar spectra from the first two years of APOGEE observations (and including data from the instrument commissioning phase) is revealing an interesting multi-dimensional view of the inner bulge and its metal distribution. We will present these new results and discuss them in the context of a bar scenario for bulge formation, as suggested by recently published observations from other surveys.

403.04 – Exploring Stellar Populations and Asteroseismology with APOGEE and Kepler

Courtney R. Epstein[1], Yvonne P. Elsworth[2], Matthew D. Shetrone[3], Benoit Mosser[4], Jamie Tayar[1], Paul Harding[5], Marc H. Pinsonneault[1], Víctor Silva Aguirre[6], Sarbani Basu[7], Dmitry Bizyaev[8], Tim Bedding[9], William J. Chaplin[2], Rafael Garcia[10], Ana Elia Garcia Perez[11], Fred Hearty[11], Saskia Hekker[12], Daniel Huber[13], Inese I. Ivans[14], Steven Majewski[11], Savita Mathur[15], Aldo Serenelli[16], Ricardo P. Schiavon[17], Ralph Schoenrich[1], Jennifer Sobeck[18], Gail Zasowski[19]

1. Ohio State University, Columbus, OH, United States. 2. University of Birmingham, Birmingham, United Kingdom. 3. The University of Texas at Austin, Austin, TX, United States. 4. LESIA, CNRS, Université Pierre et Marie Curie, Université Denis Diderot, Observatoire de Paris, Meudon Cedex, France. 5. Case Western Reserve University, Cleveland, OH, United States. 6. Aarhus University, Aarhus, Denmark. 7. Yale University, New Haven, CT, United States. 8. Apache Point Observatory, Sunspot, NM, United States. 9. University of Sydney, Sydney, NSW, Australia. 10. Laboratoire AIM, CEA/DSM-CNRS, Université Paris, Gif-sur-Yvette, France. 11. University of Virginia, Charlottesville, VA, United States. 12. Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany. 13. NASA Ames Research Center, Moffett Field, CA, United States. 14. The University of Utah, Salt Lake City, UT, United States. 15. Space Science Institute, Boulder, CO, United States. 16. Institute of Space Sciences, Bellaterra, Spain. 17. Astrophysics Research Institute, Liverpool, United Kingdom. 18. Université de Nice, Nice, France. 19. Johns Hopkins University, Baltimore, MD, United States.

Accurate measurements of fundamental stellar properties are vital for improving our understanding of stellar populations and galactic evolution. Asteroseismology makes possible precise measurements of stellar mass, radius, and surface gravity. Combining these asteroseismic measurements with spectroscopic temperatures and abundances enables the derivation of precise ages for field stars. To achieve that goal, two complementary surveys, the Apache Point Observatory Galactic Evolution Experiment (APOGEE) and the Kepler Asteroseismic Science Consortium (KASC), are working together to characterize the fundamental properties thousands of red giants in the Kepler field. As a first step toward deriving ages, asteroseismic masses need to be calibrated with independent mass constraints. I will describe how we use a sample of halo stars to test asteroseismic results in the metal-poor regime. The age of halo stars is well constrained by many lines of evidence, including isochrones fits to globular clusters, white dwarf cooling sequence, and the radioactive decay of uranium and thorium. These age constraints translate to a strict prior on halo star masses. I show that the seismic masses are sensitive to the method used to derive seismic parameters and to published, theoretically motivated corrections. The implications of this work for stellar populations are discussed.

403.05 – Exploring the Diffuse Interstellar Medium with SDSS-III APOGEE

Gail Zasowski[1], Brice Ménard[1], Steven Majewski[2], Mathias Schultheis [3], Kristen Sellgren[4]
1. Johns Hopkins University, Baltimore, MD, United States. 2. University of Virginia, Charlottesville, VA, United States. 3. Observatoire de la Cote d'Azur, Nice, France. 4. The Ohio State University, Columbus, OH, United States.

The Apache Point Observatory Galactic Evolution Experiment (APOGEE, part of the SDSS-III) is a high resolution, near-IR spectroscopic survey of 100,000 giant stars throughout the Milky Way's bulge, disk, and halo. While a primary goal of APOGEE is analysis of the chemistry and kinematics of the stars themselves, many of the stellar spectra have also been found to contain diffuse interstellar bands (DIBs), absorption features arising from unidentified molecules in the foreground interstellar medium (ISM). DIBs have been studied for nearly a century at optical wavelengths, but the first H-band lines were not published until 2011. APOGEE's large sample size and expansive spatial coverage enable us to detect and characterize these features in a homogeneous way along several thousand sight-lines that probe a wide range of Galactic environments. We present this catalog of near-IR DIBs, which is significantly larger than any other homogeneous sample of DIBs (including those at optical wavelengths), and use it to map the DIB strength within the Milky Way and to correlate detected DIB strengths and velocities with those of other Galactic ISM tracers. This analysis demonstrates the power of such large datasets to provide new insights into the properties of these poorly-understood feature carriers and the ISM in which they reside.

403.06 – CHARACTERIZING KEPLER ECLIPSING BINARIES & PLANET HOSTS WITH SDSS-III APOGEE

Suvrath Mahadevan[1]
1. Penn State, University Park, PA, United States.
Contributing teams: SDSS-III EB ancillary program team, SDSS-III Kepler dark time team

The Sloan Digital Sky Survey (SDSS-III) fiber-fed multi-object APOGEE spectrograph enables H-band spectra to be obtained for 300 targets simultaneously at a spectral resolution of R~22500. Along with the main APOGEE survey, designed to study galactic kinematics, fiber and fields have been dedicated to multi-epoch observations of Eclipsing Binaries (EBs) and planet host candidates in the Kepler field of view. Data for the EBs is already in hand and I will discuss initial results from detailed analysis of a subset of the ~100 EBs observed by APOGEE. Even with the faint Kepler targets the NIR APOGEE instrument enables the detection of low mass stellar companions and SB2 orbits using the two-dimensional cross-correlation (TODCOR) technique. For a subset of the EBs (54) we have also obtained high- resolution spectroscopic observations with the Hobby Eberly Telescope(HET). These observations, coupled with the Kepler lightcurves, allow us to derive masses and radii to better than 3%. A survey of over 150 Kepler planet hosts is also underway with SDSS-III to determine the binary environment of the planet candidates and use the APOGEE spectra to derive elemental abundances for the planet candidates.

403.07 – The APOGEE view of Be stars

Stephen S. Eikenberry[1], S. Drew Chojnowski[2], John P. Wisniewski[3], Steven R. Majewski[2], Matthew D. Shetrone[4], David G. Whelan[5,2], Dmitry Bizyaev[6], H. Jacob Borish[2], James R. Davenport[7], Garrett Ebelke[6], Diane Feuillet[6], Alan Garner[1], Fred Hearty[2], Jon A. Holtzman[6], Zhi-Yun Li[2], Sz Meczaros[8], David L. Nidever[9], Donald P. Schneider[10], Michael F. Skrutskie[2], John C. Wilson[2], Gail Zasowski[11]
1. University of Florida, Gainesville, FL, United States. 2. University of Virginia, Charlottesville, VA, United States. 3. University of Oklahoma, Norman, OK, United States. 4. University of Texas, Austin, TX, United States. 5. Hampden-Sydney College, Hampden-Sydney, VA, United States. 6. New Mexico State University, Las Cruces, NM, United States. 7. University of Washington, Seattle, WA, United States. 8. Instituto de Astrofisica de Canarias, La Laguna, Tenerife, Spain. 9. University of Michigan, Ann Arbor, MI, United States. 10. The Pennsylvania State University, State College, PA, United States. 11. Johns Hopkins University, Baltimore, MD, United States.

I will present an overview of the 100+ previously unidentified Be stars discovered during the APOGEE survey. I will particularly focus on the new highly-magnetized Rigidly Rotating Magnetosphere (RRM) stars of the Sigma Orionis E type we have found. Both of the discovered stars show the spectroscopic signatures of the rigidly rotating magnetospheres common to this class of highly-magnetized (B ?10 kiloGauss) stars. One (ABES-050) is an early main-sequence B star with unusually strong He absorption (similar to Sig Ori E), while the other (ABES-075) appears to be "He-normal" with a B3 IV subtype - the first known magnetized RRM star that is He-normal and possibly off the main sequence. We combine the APOGEE discovery spectra with other optical and near-infrared spectra of these two stars, as well as of Sig Ori E itself, to show how near-infrared spectroscopy can be a powerful tool for discovering more of these rare objects. We discuss the potential for further discovery of Sig Ori E type stars, as well as the implications of our discoveries for the population of these objects and insights into their origin and evolution.

404 – Astronomy Across Africa: A New Dawn

Special Session – Maryland 1 – 09 Jan 2014 10:00 am to 11:30 am

One of the youngest and fastest growing astronomy communities in the world is on the African continent. In the past couple of decades and in the upcoming decades an explosion of cutting edge multi-wavelength facilities have begun or are expected to be operating namely SALT, HESS, MITRA, AVN, PAPER, MeerKAT, African VLBI and the SKA (Acronyms described at the end of this document). At the same time countries across the continent are developing human capacity in science and technology using astronomy as a gateway science. As astronomy is set to explode across Africa, its astronomy community, facilities and on-going science remain relatively unknown to the US community. With this special session(s) request we seek to change this situation by providing an overview of facilities, human capacity development programs and astronomy development work from a diverse set of both US and African astronomers engaged in these activities.

404.01 – Astronomy Across Africa

Ted Williams[1, 2]
1. South African Astronomical Observatory, Cape Town, South Africa. 2. Rutgers University, New Brunswick, NJ, United States.

African astronomy is growing rapidly. The Southern African Large Telescope is the largest optical telescope in the southern hemisphere, MeerKat and the Square Kilometer Array will revolutionize radio astronomy in the coming decade, and Namibia hosts HESS II, the world's largest gamma-ray telescope. A growing community of observational and theoretical astronomers utilizes these multi-wavelength observational facilities. The largest concentrations of researchers are in southern Africa, but the community is now expanding across the continent. Substantial resources are being invested in developing the next generation of African astronomers. The African Astronomical Society was formed in 2011 to foster and coordinate the growth of the science in Africa. The IAU has located its global Office of Astronomy for Development in South Africa, with the mandate to find innovative ways of using astronomy to promote social and educational development around the world. African astronomy offers abundant opportunities for collaborative research with colleagues from across the globe. This special session will introduce many of the aspects of African astronomy to the US community, with the aim of engendering new partnerships and strengthening existing ones.

404.02 – Dissecting galaxies with the Southern African Large Telescope (SALT)

Ilani Loubser[1]
1. North-West University, Potchefstroom, South Africa.

Coined 'Africa's Giant Eye on the Universe' by past president Thabo Mbeki, the Southern African Large Telescope (SALT) is the largest single optical telescope in the Southern hemisphere and among the largest in the world. It's primary mirror measures 11 metres across, and it has now been observing in full swing since September 2011. Here, we will give a very brief introduction to the instrumentation available, as well as highlight some recent results obtained from spectroscopy on SALT to dissect the spatially-resolved kinematics and stellar populations of cluster galaxies.

404.03 – Legacy Science Surveys with the MeerKAT

Sarah Blyth[1]
1. University of Cape Town, Cape Town, Western Cape, South Africa.

The MeerKAT radio telescope array, currently under construction in the Northern Cape, South Africa, is a precursor instrument for the Square Kilometre Array (SKA) and will hold the title for the largest radio interferometer in the world until the SKA comes online in 2020. In 2009, a request for proposals was put out to the international astronomy community for large survey projects to fill 70% of the available observing time. After review by an international panel, ten projects were chosen in line with performing SKA-precursor science. In this talk, I will present an overview of these upcoming legacy surveys which will cover a broad spectrum of research areas ranging from studies of galaxy evolution over cosmic time (via neutral hydrogen and radio continuum observations), to sensitive radio pulsar timing measurements, to searches for radio transient sources to name but a few.

404.04 – Exploring Our Cosmic Dawn from South Africa

Aaron Parsons[1]
1. University of California, Berkeley, Berkeley, CA, United States.
Contributing teams: PAPER, Square Kilimetre Array South Africa

The Precision Array to Probe the Epoch of Reionization (PAPER) is a dedicated experiment for using radio emission from neutral hydrogen to access one of the last major phase transitions in our Universe --- the epoch when the first luminous objects ionized the bulk of the hydrogen in the universe. PAPER has been deployed in the Karoo desert of South Africa since 2009, and has been co-developed with the help of Square Kilometre Array South Africa (SKASA), students and researchers at

the University of Cape Town, and many interns from local technical colleges. Shared efforts between SKASA and UC Berkeley developing digital signal processing hardware for PAPER helped begin the Collaboration for Astronomy Signal Processing and Electronics Research (CASPER), which now includes hundreds of organizations around the world who use CASPER technology in a wide range of astronomy applications. We discuss the history and current status of collaboration between PAPER and organizations in South Africa, its numerous synergistic benefits, and the prospects for broadening and enriching this collaboration as part of a next-generation instrument to succeed PAPER: the Hydrogen Epoch of Reionization Array (HERA).

404.05 – Building the Next Generation of Scientists with US-Africa Exchange Programs

Kartik Sheth[1]

1. NRAO, Charlottesville, VA, United States.

In the past couple of decades and in the upcoming decade an explosion of cutting edge multi-wavelength facilities have begun or are expected to be operating across the African continent (SALT, HESS, MITRA, AVN, PAPER, MeerKAT, African VLBI and the SKA). At the same time countries across the continent are developing human capacity in science and technology using astronomy as a gateway science. Building on previous collaborations between the National Radio Astronomy Observatory and South Africa, we are embarking on an effort to build a new international (and national) partnership to exchange students and faculty between the US and the African continent. I will describe the status and future development plans for this program.

404.06 – Astronomy for Development in Africa

Jean-Christophe Mauduit[1]

1. California Institute of Technology, Pasadena, CA, United States.

This presentation will look briefly at efforts to stimulate astronomy across Africa and will broadly summarize the current status of astronomy on the continent. It will also aim to address the question of how astronomy can be used for African development - something that has always been a key driver of efforts to grow the field in this region. The establishment of the IAU's Office of Astronomy for Development, which has a global mandate, has provided additional support and opportunity for the many role players across the African continent. These individuals had already organised themselves in order to grow the field of astronomy across all areas from outreach to education to research. Some of these activities built on work done by the IAU's Commission 46 (Astronomy Education and Development) while other activities stemmed from the International Year of Astronomy 2009, specifically the "Developing Astronomy Globally" Cornerstone Project.

404.07 – Vision for Astronomy in South Africa and partnership with the US

Takalani Nemaungani[1]

1. Department of Science and Technology, Pretoria, Gauteng, South Africa.

The 2002 National Research and Development Strategy identified astronomy as a national geographic advantage. This identification was based on the historical investments in optical and, to a lesser extent, radio astronomy up to that point and the realisation that the conditions prevailing in Sutherland were among the best in the world. Since then a number of astronomy initiatives have burgeoned in the Southern African region and these include the HESS, SKA and the AVN. Currently, investments in astronomy are by far the biggest investments being made by the Department of Science and Technology (DST). South Africa's involvement in modern astronomy dates back to 1685 when a French Astronomer, Guy Tachard, setup an observatory at the southern tip of Africa to decipher the star charts of the extreme southern sky. In 1820, a permanent observatory – the Royal Observatory - was established outside of Cape Town and astronomy has been practised continuously since then. By the late 1980s, it became clear that for South African astronomers and astrophysicists to continue conducting first class research, the acquisition of a much larger, powerful and sophisticated telescope would be necessary. This provided the impetus for a new vision to construct the largest single optical telescope in the Southern Hemisphere, eventually known as the Southern African Large Telescope (SALT). Within the last decade, the African appetite for radio astronomy initiatives has increased exponentially. This has largely been spurred by the African bid to host the SKA project and the need for African countries to work in close partnership that consequently resulted in a successful bid to co-host the SKA project and the subsequent need to ensure its effective implementation. This partnership, and the interactions related thereto, has effectively enhanced awareness around the requirements for hosting radio astronomy instrumentation and the associated benefits that could be derived in making such commitments. Consequently, there have been concerted efforts in support of various radio astronomy initiatives that sit at the cusp of the continents ambitions for the hosting of the SKA.

405 – Binary Systems - Dwarfs and Giants

Oral Session – Maryland 2 – 09 Jan 2014 10:00 am to 11:30 am

405.01D – The X-ray and Spectropolarimetric View of Mass Loss and Transfer in Massive Binary Stars

Jamie R. Lomax[1,2]

1. University of Denver, Denver, CO, United States. 2. University of Oklahoma, Norman, OK, United States.

The majority of massive stars are members of binary systems. However, in order to understand their evolutionary pathways, mass and angular momentum loss from these systems needs to be well characterized. Self-consistent explanations for their behavior across many wavelength regimes need to be valid in order to illuminate key evolutionary phases. In this talk I will present the results of an X-ray and spectropolarimetric study of three key binaries: beta Lyrae, V444 Cyg, and WR 140. In beta Lyrae, I will show a repeatable discrepancy between secondary eclipse in the total and polarized light curves indicates an accretion hot spot has formed on the edge of the disk in the system. The existence of this hot spot and its relationship to bipolar outflows within the system is important in the understanding of mass transfer dynamics in Roche-lobe overflow binaries. For V444 Cyg, I will present the results of an X-ray and polarimetric monitoring campaign which indicate the effects of radiative inhibition or braking, and the Coriolis force can be significant contributors to the location and shape of the shock within colliding wind binaries. Additionally, I will present data from WR 140 that suggest unexpected intrinsic hard X-ray emission may be present at some and argue that better polarimetric monitoring of the system is needed. Continued work on these and additional objects will provide new and important constraints on the mass loss structures within binary systems. This research includes contributions from collaborators at the University of Denver, NASA/GSFC, The Universite de Liege, The University of Toledo, East Tennessee State University, The University of Leeds, ESA, Hokkai-Gakuen University, NRAO, The University of Delaware, and Vanderbilt University. Additionally, I acknowledge support from the NASA Harriett G. Jenkins Pre-doctoral Fellowship Program, Sigma Xi's Grants-in-Aid of Research Program, and NASA ADAP award NNH12ZDA001N.

405.02 – A Cornucopia of Massive Binary Star Systems in the Cygnus OB2 Association: Fifty and Counting

Henry A. Kobulnicky[1], Daniel C. Kiminki[2,1], Jamison F. Burke[1,3], James E. Chapman[1,4], Erica Keller[1,5], Katie V. Lester[1,6], Emily Rolen[1,7], Eric Topel[1,8], Michael J. Lundquist[1], Anirban Bhattacharjee[1], Carlos A. Vargas Alvarez[1], Jessie C. Runnoe[9,1], Daniel A. Dale[1]

1. Univ. of Wyoming, Laramie, WY, United States. 2. University of Arizona, Tucson, AZ, United States. 3. Swarthmore College, Swarthmore, PA, United States. 4. Massechusetts College of Liberal Arts, North Adams, MA, United States. 5. Mount Holyoke College, South Hadley, MA, United States. 6. Leheigh University, Bethlehem, PA, United States. 7. Vanderbilt University, Nashville, TN, United States. 8. St. Olaf College, Northfield, MN, United States. 9. Penn State University, University Park, PA, United States.

Massive binary star systems produce nature's most energetic events, including some classes of supernovae, gamma-ray bursts, X-ray binaries, and double-degenerate objects that generate gravitational wave radiation. The Cygnus OB2 Association is the largest nearby collection of massive stars, consisting of several hundred O and early B stars at a distance of just 1.4 kpc. Our Cygnus OB2 Radial Velocity Survey team at the University of Wyoming has spectroscopically monitored 115 stars of type B2 or earlier between 1999 and 2013, accruing an average of 12 observations per star at a velocity precision of 2-6 km/s. We have identified fifty massive binary systems, nearly all of which have full orbital solutions. Periods range from 1.4 days - 12.5 years and velocity semi-amplitudes span 4-300 km/s. Monte-Carlo modeling indicates that as many as 90% of massive systems contain multiple stars and that 45% of these can be characterized as ``close'' binaries that will interact, exchanging matter during main-sequence or post-main-sequence evolution. Statistical analysis of the orbital parameters reveals a striking surplus of close, short-period systems with periods P=1.4--7 days, with fully 30% (17 out of 50 systems) of the known binaries falling in this tight range; their typical orbital separations are just a small fraction of an astronomical unit. The remainder of the binary systems are consistent with a period distribution described as flat in log(P) out to several thousand day periods. The mass ratio distribution appears flat over the interval q=M2/M1=0.1-1.0, meaning that massive stars preferentially have massive companions. These data constitute the largest and most complete homogeneous database on any single collection of massive stars in a common formation environment covering the full range of stars expected to explode as supernovae (B2V and earlier). As such, the Survey provides the raw data for modeling rates of cosmic supernova, gamma-ray bursts, and X-ray binaries while informing theories of massive star formation that should be expected to reproduce the observed distributions of orbital periods and mass ratios.

405.03 – Eta Carinae: An Astrophysical Laboratory to Study Conditions During the Transition Between a Pseudo-Supernova and a Supernova

Darren McKinnon[1], Theodore R. Gull[2], Thomas Madura[2]
1. Utah State University, Logan, UT, United States. 2. NASA GSFC, Greenbelt, MD, United States.

A major puzzle in the studies of supernovae is the pseudo-supernova, or the near-supernovae state. It has been found to precede, in timespans ranging from months to years, a number of recently-detected distant supernovae. One explanation of these systems is that a member of a massive binary underwent a near-supernova event shortly before the actual supernova phenomenon. Luckily, we have a nearby massive binary, Eta Carinae, that provides an astrophysical laboratory of a near-analog. The massive, highly-eccentric, colliding-wind binary star system survived a non-terminal stellar explosion in the 1800's, leaving behind the incredible bipolar, 10"x20" Homunculus nebula. Today, the interaction of the binary stellar winds (~1") is resolvable by the Space Telescope Imaging Spectrograph (STIS) aboard the Hubble Space Telescope (HST). Using HST/STIS, several three-dimensional (3D) data cubes (2D spatial, 1D velocity) have been obtained at selected phases during Eta Carinae's 5.54-year orbital cycle. The data cubes were collected by mapping the central 1-2" at 0.05" intervals with a 52"x0.1" aperture. Selected forbidden lines, that form in the colliding wind regions, provide information on electron density of the shocked regions, the ionization by the hot secondary companion of the primary wind and how these regions change with orbital phase. By applying various analysis techniques to these data cubes, we can compare and measure temporal changes due to the interactions between the two massive winds. The observations, when compared to current 3D hydrodynamic models, provide insight on Eta Carinae's recent mass-loss history, important for determining the current and future states of this likely nearby supernova progenitor.

405.04 – A Tale of Two Red Giants: Testing Asteroseismic Scaling Relations with KIC 9246715

Meredith L. Rawls[1], Patrick Gaulme[1], Jean McKeever[1], Jerome A. Orosz[2], David W. Latham[3], Jason Jackiewicz[1]
1. New Mexico State University, Las Cruces, NM, United States. 2. San Diego State University, San Diego, CA, United States. 3. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

We present a thorough characterization of the double red-giant eclipsing binary KIC 9246715. Because one of the two stars shows clear pulsations, this system is an ideal empirical test of asteroseismic scaling relations. We combine Kepler light curves and ground-based radial velocity curves for both stars to derive a best-fit orbital solution for the system, which includes masses and radii. We then compare results from this well-established technique to those from asteroseismology. The red giant asteroseismic scaling laws are a promising way to characterize these stars quickly, and are not limited to binary systems with extensive radial velocity data. Interestingly, the two red giants in this binary system are very similar physically, yet only one shows detectable pulsations. We comment on the possible implications of this, and discuss how our results can help inform ensemble asteroseismology.

405.05 – Fundamental Properties of Eclipsing Binaries in the Kepler field of view

Rachel A. Matson[1], Douglas R. Gies[1], Zhao Guo[1]
1. GSU, Atlanta, GA, United States.

Eclipsing binaries play an important role in stellar astrophysics as the main source of fundamental mass and radius measurements, in addition to providing estimates of effective temperatures, metallicities, and other stellar properties. The Kepler spacecraft has produced exquisite light curves of over 2000 eclipsing binaries allowing unprecedented analysis of such systems. Using Kepler photometry and moderate resolution optical spectra we are determining fundamental properties of 41 close, intermediate-mass eclipsing binaries. We use a 2-D cross correlation technique to determine radial velocities and spectroscopic orbital solutions for each system. In addition, we reconstruct the spectra of the individual binary components and compare them to libraries of synthetic spectra to determine effective temperatures, surface gravities, and rotational velocities. Using these data and constraints we then model the Kepler light curves and determine the fundamental properties of each system.

406 – Black Holes I
Oral Session – National Harbor 10 – 09 Jan 2014 10:00 am to 11:30 am

406.01 – Twisted Disks: General Relativistic Simulations of Thin Accretion Disks With A Tilted Black Hole

Mark J. Avara[1], Jonathan C. McKinney[1, 2], Christopher S. Reynolds[1, 2]
1. University of Maryland, College Park, College Park, MD, United States. 2. Joint Space-Science Institute, University of Maryland, College Park, MD, United States.

Much of our current interpretation of observations of black hole accretion disks assumes either 1) a simplified non-warped geometry in which the inner radius of the accretion disk is set by the spin of the black hole (BH) as if the disk and BH were aligned; or 2) a warped disk with the geometric structure described as the Bardeen-Petterson (BP) effect. Since there is no *a priori* reason to assume disks and BH spins are always aligned in real systems, a physical model used to interpret observations must assume a warped geometry to give accurate physical insight. However, simulations of disks warped via the BP effect have only been achieved so far by making non-trivial simplifying assumptions, and most do not capture the magnetohydrodynamics necessary to realistically model such a disk. We present our latest results from fully general relativistic MHD simulations of thin BH accretion disks aimed at specifically capturing the diffusive BP (static warp) regime.

406.02 – Tidal Disruption Events from Archival X-ray Observations of Dwarf Galaxies

W. P. Maksym[1], Jimmy Irwin[1], Melville P. Ulmer[2], Katherine Roth[3], Renato A. Dupke[4, 5], Luis C. Ho[6], William C. Keel[1], Christophe Adami[7], Dacheng Lin[1]
1. University of Alabama, Tuscaloosa, AL, United States. 2. Northwestern University, Evanston, IL, United States. 3. Gemini Observatory North, Hilo, HI, United States. 4. Observatorio Nacional, Río de Janeiro, Río de Janeiro, Brazil. 5. University of Michigan, Ann Arbor, MI, United States. 6. Carnegie Observatories, Pasadena, CA, United States. 7. Laboratoire d'Astrophysique de Marseille, Marseille, Bouches-du-Rhône, France.

Intermediate-mass black holes (IMBHs) have proven notably difficult to identify unambiguously. The luminous flare resulting from an IMBH's disruption of a passing star is one particularly promising method of identifying IMBHs. We present recent results on tidal disruption candidates in dwarf galaxies, which we have identified in archival X-ray data. In particular, we discuss deep Gemini spectroscopy of the tidal disruption host galaxy WINGS J134849.88+263557.5, which we had previously identified in Abell 1795 via an archival survey of Galaxy clusters using Chandra and XMM-Newton. We eliminate the interpretation of this object as a background galaxy or flaring AGN with weak emission lines, and now confirm that this galaxy is a passive dwarf galaxy in Abell 1795 and one of the smallest galaxies confirmed to host a massive black hole. We also discuss another possible tidal disruption identified via comparison of archival ROSAT and XMM-Newton data, which shows a luminous, supersoft, and highly variable X-ray source in an otherwise inactive dwarf galaxy.

406.03D – Understanding X-ray Reflection as a Probe of Accreting Black Holes

Dan Wilkins[1, 2]
1. Institute of Astronomy, University of Cambridge, Cambridge, United Kingdom. 2. St Mary's University, Halifax, NS, Canada.

Active galactic nuclei (AGN) are some of the most luminous objects we see in the Universe, powered by the accretion of matter onto a supermassive black hole in the centre of a galaxy, yet many of the physical processes by which the energy is released and injected into the surroundings remain a mystery. X-rays are emitted from a 'corona' of energetic particles surrounding the black hole and as well as being observed directly, they are seen to be reflected from the accreting disc, producing a number of spectral features including emission lines that are broadened by relativistic effects in the proximity of the black hole. In my thesis, I develop methods through which detailed measurement of the reflected X-rays from the accretion disc can be used to probe the innermost regions of accretion flow and corona, right down to the innermost stable orbit and the event horizon. Novel spectral analysis techniques allow us to reconstruct, from the observed relativistic X-ray reflection spectrum the spatially resolved illumination pattern of the accretion disc and will discuss how comparing this to the results of systematic general relativistic ray tracing simulations I have developed, we are able to constrain the location and geometry of the X-ray emitting corona and understand the dramatic change of the narrow line Seyfert 1 galaxy 1H 0707-495 into an extremely low flux state in terms of a collapse in the corona. I will discuss how measurements of the X-ray variability, specifically the reverberation time lags that are observed between variability in the directly observed X-rays from the corona and those reflected from the accretion disc add a further dimension to the study of accreting black holes, letting us not only build up a three dimensional image of the immediate vicinity of the black hole but also to probe mechanisms by which the energy is released from the accretion flow; techniques that will let us exploit not just current instrumentation but future proposed X-ray observatories to really put theories of black holes and accretion to the test and understand such

extreme objects and how they shape Universe.

406.04 – The Relativistically Beamed Tidal Disruption Event Sw J1644+57

John K. Cannizzo[1]
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Sw J1644+57 made a dramatic appearance in March 2011, and has been the focus of intense observations spanning a wide wavelength range. It has also stimulated much theoretical work on tidal disruption events in general and jetted events in particular. Sw 1644 was unexpected; almost all previous work on TDEs, both theoretical and observational, had been centered on observational properties of the thermal emission from the accretion. In Sw 1644 our line of sight lies along the SMBH jet, so that we see only the boosted, jet emission. There now exists a ~500 d light curve of the burst from Swift/XRT. I will provide an overview of the current observational and theoretical status.

406.05 – The Megasecond Chandra X-ray Visionary Project Observation of NGC 3115: Nature of Hot Gas within the Bondi Radius

Ka-Wah Wong[1], Jimmy Irwin[1], Roman V. Shcherbakov[2], Mihoko Yukita[1, 3], Evan Million[1], Joel N. Bregman[4]
1. University of Alabama - Tuscaloosa, Tuscaloosa, AL, United States. 2. University of Maryland, College Park, MD, United States. 3. Johns Hopkins University, Baltimore, MD, United States. 4. University of Michigan, Ann Arbor, MI, United States.

Observational confirmation of hot accretion model predictions has been hindered by the challenge to resolve spatially the Bondi radii of black holes with X-ray telescopes. The closest billion solar mass black hole in NGC 3115 provides such an opportunity. We present results from our Megasecond Chandra X-ray Visionary Project (XVP) observation of NGC 3115 to study the most detailed spatially and spectroscopically resolved structures of the X-ray-emitting gas inside the Bondi radius a black hole. Temperature and density profiles of the hot gas were measured from a fraction out to tens of the Bondi radius (R_B = 2.4-4.8 arcsec = 112-224 pc). In contrary to the expectation that the temperature should be rising toward the center for the radiatively inefficient accretion flow in NGC 3115, we found that there is significant softer emission (~0.3 keV) within a scale of 3 arcsec (~150 pc) compared to a simple hot accretion model. A hotter thermal component of ~1 keV inside 3 arcsec, which is closer to the predictions of hot accretion models, is revealed when we modeled the projected spectra using a two component thermal model, with the cooler ~0.3 keV thermal component dominating the spectra. We discuss possible origins of the softer thermal component and implications of the results.

406.06 – Evidence for Enhanced Formation Rate of Black Hole LMXBs in the Galaxy from Historical Outbursts from DASCH

Jonathan E. Grindlay[1], George F. Miller[1], Sumin Tang[2]
1. Harvard-Smithsonian, CfA, Cambridge, MA, United States. 2. UCSB, Santa Barbara, CA, United States.

Using the data releases DR1 and DR2 as well as from the "Development Fields" from DASCH (Digital Access to a Sky Century @ Harvard), we have searched for historical optical outbursts of black hole low mass X-ray binaries (BH-LMXBs). With now 4 systems (XTEJ1118+480, GROJ1655-40, V4641Sgr and V404 Cyg) at least partially covered by the ongoing production DASCH plate scanning of the ~500,000 plates in the Harvard archives, we have discovered single or single + "echo" historical outbursts from each of these 4 BH-LMXBs over the past century of coverage available from DASCH. This provides the first confirmation of what was suspected from the single historical outbursts previously reported for outbursts from A0620-00 (from the Harvard plates) and the "hiistorical nova" V404 Cyg and greatly strengthens the case that these systems have much lower duty cycles than the otherwise similar "X-ray novae" from NS-LMXBs. This, in turn, suggests that their total population or rate of formation may exceed that for NS-LMXBs, when allowing for a Kroupa IMF for BH vs. NS production and plausible differences in outburst peak luminosity that impose selection effects in their discovery wihch until now has been with wide-field X-ray (or hard X-ray) surveys such as BATSE, RXTE/ASM, Swift/BAT and MAXI. By the time of this presentation, more confirmed BH-LMXBs may have been scanned in the ongoing DASCH scanning that will provide an even larger sample (which will extend ultimately to the full sample of ~25 BH-LMXBs now dynamically confirmed). Comparisons will be made with the known NS-LMXB X-ray transient sample and their duty cycle for comoparison with the the BH-LMXBs to derive new constraints on total populations for each and the implications for both their formation mechanisms in the Galaxy.The (rare) optical "transients" produced by BH-LMXB outbursts due to the accretion disk instability model may be be searched for independently (of known BH-LMXBs) in the DASCH data, which will provide a new way of constraining the stellar mass black hole population in the Galaxy. DASCH development, and now production scanning has been supported by the NSF (currently AST-1313370), for which we are grateful

407 – Cosmology & CMB V
Oral Session – National Harbor 13 – 09 Jan 2014 10:00 am to 11:30 am

407.01 – CMB cosmology on small scales with ACT and ACTPol

Renee Hlozek[1]
1. Princeton University, Princeton, NJ, United States.
Contributing teams: ACT and ACTPol teams

The Atacama Cosmology Telescope (ACT) has mapped the microwave sky to arcminute scales. We will review the cosmological results from three seasons of ACT data and present a status report for the polarization-sensitive ACTPol telescope, which will considerably improve constraints on primordial cosmological parameters through its high-resolution measurement of the EE polarisation spectrum, and the measurement of the small-scale B-modes produced from lensing.

407.02D – The Cosmology Large Angular Scale Surveyor (CLASS)

Joseph Eimer[1], Aamir Ali[1], Mandana Amiri[6], John W. Appel[1], Derek Araujo[7], Charles L. Bennett[1], Fletcher Boone[1], Manwei Chan[1], Hsiao-Mei Cho[3], David T. Chuss[2], Felipe Colazo[2], Erik Crowe[2], Kevin Denis[2], Rolando Dünner[4], Thomas Essinger-Hileman[1], Dominik Gothe[1], Mark Halpern[6], Kathleen Harrington[1], Gene Hilton[3], Gary F. Hinshaw[6], Caroline Huang[1], Kent Irwin[3], Glenn Jones[7], John Karakla[1], Alan J. Kogut[2], David Larson[1], Michele Limon[7], Lindsay Lowry[1], Tobias Marriage[1], Nicholas Mehrle[1], Amber D. Miller[7], Nathan Miller[2], Samuel H. Moseley[2], Giles Novak[8], Carl Reintsema[3], Karwan Rostem[2], Thomas Stevenson[2], Deborah Towner[2], Kongpop U-Yen[2], Emily Wagner[1], Duncan Watts[1], Edward Wollack[2], Zhilei Xu[1], Lingzhen Zeng[5]
1. Johns Hopkins University, Baltimore, MD, United States. 2. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 3. NIST, Boulder, CO, United States. 4. Pontifica Universidad Catolica de Chile, Santiago, Chile. 5. CfA-SAO, Cambridge, MA, United States. 6. University of British Columbia, Vancouver, BC, Canada. 7. Columbia University, New York, NY, United States. 8. Northwestern University, Chicago, IL, United States.

The Cosmology Large Angular Scale Surveyor (CLASS) is an array of telescopes designed to search for the signature of inflation in the polarization of the Cosmic Microwave Background (CMB). By combining the strategy of targeting large scales (>2 deg) with novel front-end polarization modulation and novel detectors at multiple frequencies, CLASS will pioneer a new frontier in ground-based CMB polarization surveys. In this talk, I give an overview of the CLASS instrument, survey, and outlook on setting important new limits on the energy scale of inflation.

407.03D – EBEX: A Balloon-Borne CMB Polarization Experiment

Daniel Chapman[1], Asad M. Aboobaker[2], Peter Ade[3], Francois Aubin[2], Carlo Baccigalupi[4], Kevin Bandura[5], Chaoyun Bao[2], Julian Borrill[6, 7], Joy Didier[1], Matt Dobbs[5], Ben Gold[2], Julien Grain[8], Will Grainger[3], Shaul Hanany[2], Kyle Helson[9], Seth N. Hillbrand[1], Gene Hilton[10], Hannes Hubmayr[2], Kent Irwin[10], Bradley Johnson[11], Andrew Jaffe[12], Terry J. Jones[2], Theodore Kisner[6], Jeffrey Klein[2], Andrei Korotkov[9], Samuel Leach[4], Adrian T. Lee[11], Lorne Levinson[13], Michele Limon[1], Kevin MacDermid[5], Amber D. Miller[1], Michael Milligan[2], Enzo Pascale[3], Kate Raach[2], Britt Reichborn-Kjennerud[1], Ilan Sagiv[13], Graeme Smecher[5], Radek Stompor[14], Matthieu Tristram[15], Gregory S. Tucker[9], Benjamin Westbrook[11], Kyle Zilic[2]
1. Columbia University, New York, NY, United States. 2. University of Minnesota School of Physics and Astronomy, Minneapolis, MN, United States. 3. Cardiff University, Cardiff, Glamorgan, United Kingdom. 4. Scuola Internazionale Superiore di Studi Avanzati (SISSA), Trieste, Trieste, Italy. 5. McGill University, Montreal, QC, Canada. 6. Lawrence Berkeley National Laboratory, Berkeley, CA, United States. 7. University of California, Berkeley, Space Sciences Lab, Berkeley, CA, United States. 8. Institut d'Astrophysique Spatiale, Universite Paris-Sud, Orsay, Ile-de-France, France. 9. Brown University, Providence, RI, United States. 10. NIST Quantum Devices Group, Boulder, CO, United States. 11. University of California, Berkeley, Berkeley, CA, United States. 12. Imperial

College, London, Greater London, United Kingdom. 13. Weizmann Institute of Science, Rehovot, Rehovot, Israel. 14. CNRS, Laboratoire Astroparticule et Cosmologie (APC), Universite Paris Diderot, Paris, Ile-de-France, France. 15. Laboratoire de l'Accélérateur Linéaire, Universite Paris-Sud, Orsay, Ile-de-France, France.

The E and B Experiment (EBEX) is a balloon-borne telescope designed to probe polarization signals in the CMB resulting from primordial gravitational waves, gravitational lensing, and Galactic dust emission. EBEX is the first balloon-borne astrophysical polarimeter to use a continuously rotating achromatic half-wave plate on a superconducting magnetic bearing and over 1000 transition edge sensor bolometers read out with SQUID amplifiers. The instrument completed an 11 day flight over Antarctica in January 2013 and data analysis is underway. We will provide an overview of the experiment and the Antarctic flight, and give an update on the analysis.

407.04D – Design of the detectors for EBEX, a balloon-borne cosmic microwave background polarimeter

Benjamin Westbrook[1, 7], Asad M. Aboobaker[2], Peter Ade[3], Francois Aubin[2], Carlo Baccigalupi[4], Kevin Bandura[5], Chaoyun Bao[2], Julian Borrill[6, 7], Daniel Chapman[11], Joy Didier[11], Matt Dobbs[5], Ben Gold[2], Julien Grain[8], Will Grainger[3], Shaul Hanany[2], Kyle Helson[9], Seth N. Hillbrand[11], Gene Hilton[10], Hannes Hubmayr[10], Kent Irwin[10], Bradley Johnson[11], Andrew Jaffe[12], Terry J. Jones[2], Theodore Kisner[6], Jeff Klein[2], Andrei Korotkov[9], Samuel Leach[4], Adrian T. Lee[1], Lorne Levinson[13], Michele Limon[11], Kevin MacDermid[5], Amber D. Miller[11], Michael Milligan[2], Enzo Pascale[3], Kate Raach[2], Britt Reichborn-Kjennerud[11], Ilan Sagiv[13], Graeme Smecher[5], Radek Stompor[14], Matthieu Tristram[15], Gregory S. Tucker[9], Kyle Zilic[2]

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The E and B Experiment (EBEX) is a balloon-borne polarimeter designed to make precision measurements of the polarization of the cosmic microwave background and the galactic foreground. We report on the design and first implementation of spiderweb-absorber transition edge sensor (TES) bolometer technology on a balloon-borne platform in EBEX. Spiderweb absorber TES bolometer technology was originally developed for the ground-based APEX-SZ and South Pole Telescope experiments and required optimization for the lower optical loading and higher frequency band operation in a balloon environment.

407.05D – The First Season of POLARBEAR Observations

David Boettger[1]
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Contributing teams: The POLARBEAR Collaboration

POLARBEAR is a cosmic microwave background (CMB) polarization experiment operating in the Atacama Desert in Chile. The first season of observations with POLARBEAR has been dedicated to searching for CMB B-mode polarization created by gravitational lensing of E-modes, and has created one of the deepest CMB polarization data sets in existence. We will describe the experiment design, performance, and analysis of the data collected.

408 – Dark Matter & Dark Energy I
Oral Session – Maryland Ballroom C – 09 Jan 2014 10:00 am to 11:30 am

408.01 – Locating the Transition Red Shift from the Scale Factor vs Look-back Time Plot

Harry I. Ringermacher[1], Lawrence R. Mead[1]
1. Dept. of Physics & Astronomy, U. of Southern Miss., Hattiesburg, MS, United States.

We combine SNLS3, 2011 SNe data of Conley, et al. with the the 2004 SNe data of Reiss, et al. and the 2004 high-Z Radio Galaxy data of R. Daly, et al. to provide a dense baseline which improves the observability of the transition redshift. We fit LCDM to the usual modulus vs. redshift plot for this data to validate the joining of the three sets. We then fit an alternate model of dark matter as a fluid (Omega-matter ~ 1/t^2) to the same data. The two plots are essentially a match. Then we derive the a(t) vs. t curve directly from this data where t is the light travel time and is derived from the luminosity distance. We fit the same two models to the new plot and find that they separate the two models more clearly. This presentation of the data as opposed to the usual Hubble diagram displays the inflection point or transition time directly and more sensitively. Finally, we estimate the transition redshift from the scale factor plot.

408.02 – Establishing the Robustness of Cosmological Tests of General Relativity to Dark Energy Perturbations

Jason Dossett[1], Mustapha Ishak[2]
1. The University of Queensland, St Lucia, QLD, Australia. 2. The University of Texas at Dallas, Richardson, TX, United States.

Cosmological tests to distinguish between dark energy and modifications to gravity are a promising route to obtain clues on the origin of cosmic acceleration. We studied the robustness of these tests to the presence of dark energy density, velocity, and anisotropic stress perturbations. I will present our results on the growth index parameter and the modified growth parameters that enter the perturbed Einstein equations. In all cases I show that models of dark energy with perturbations can be distinguished from modified gravity models. This distinction is possible either because dark energy perturbations have a less significant effect on the observable, or the effects occur at different scales than those due to modified gravity. Notably, dispersion in the value of the growth index parameter obtained for the dark energy models remains small making it the most robust method to distinguish between the two scenarios. In summary, we found that the currently proposed cosmological tests to distinguish between dark energy and modified gravity are robust to dark energy perturbations even for extreme cases. This is certainly the case even for dark energy models with equations of state of dark energy that fall well outside of current cosmological constraints.

408.03 – Too Big To Fail: A Sensitive Test of Cosmological Parameters and Dark Matter Properties

Emil Polisensky[1], Massimo Ricotti[2, 3]
1. Naval Research Lab., Washington, DC, United States. 2. University of Maryland, College Park, MD, United States. 3. Institut Lagrange de Paris, Paris, France.

We have performed dissipationless N-body simulations of four Milky Way-sized halos in three different cold dark matter and four different warm dark matter cosmologies. We investigate the "too big to fail"' problem, that the largest subhalos in simulation are dynamically inconsistent with observations of the Milky Way's most luminous satellites. We find that the inconsistency is largely attributable to the large values of ?_8 and n_s adopted in the discrepant simulations, producing satellites that form too early and therefore are too dense. We find the tension between observations and simulations adopting parameters consistent with WMAP9 is greatly diminished, making the satellites a sensitive test of CDM. We find warm dark matter cosmologies allowed by constraints from the number of Milky Way satellites and Lyman-α forest have a minor effect in reducing the densities of massive satellites. Given the uncertainties on the mass and formation epoch of the Milky Way, the need for reducing the satellite densities with baryonic effects or WDM is alleviated.

408.04 – Present and future insights into the particle physics of dark matter through strong gravitational lensing observations

Leonidas A. Moustakas[1], Francis-Yan Cyr-Racine[1, 2], Charles R. Keeton[3]
1. JPL/Caltech, Pasadena, CA, United States. 2. Keck Institute for Space Studies, Pasadena, CA, United States. 3. Rutgers, The State University of New Jersey, New Brunswick, NJ, United States.

The thermal and interaction properties of the dark matter particle or particles leave distinct imprints on how dark matter is distributed on different astronomical scales over cosmic time. These imprints are distinctive, and can be exploited through diverse observations of strong gravitational lenses, from spectroscopy, to high resolution imaging at many wavelengths, to

dense-cadence time domain mapping. I will present results on how powerful combinations of these observations can be, by application of inference techniques to the observational characteristics of the Hubble Space Telescope, ground-based Adaptive Optics observations, the OMEGA Explorer, and James Webb Space Telescope platforms.

408.05 – Warm Dark Matter N-Body Simulations and the Core-Cusp Problem of Cold Dark Matter

Brandon Bozek[1], Rosemary F. Wyse[1], Ben Elder[2]
1. Johns Hopkins University, Baltimore, MD, United States. 2. Massachusetts Institute of Technology, Cambridge, MA, United States.

The derived dark matter halo density profiles from kinematic studies of both gas-rich and gas-poor dwarf galaxies have been found to host a central core, while dark matter halos in Cold Dark Matter numerical simulations universally feature a central cusp. Cold Dark Matter simulations have invoked baryonic processes, such as strong stellar/supernova feedback, to flatten the cusp. Warm Dark Matter halos should naturally form with a cored density profile, of extent depending on the mass of the Warm Dark Matter particle, and therefore should not require such strong feedback. We investigate this core-cusp issue using a suite of high-resolution N-body simulations of the evolution of dwarf galaxy-sized dark matter halos in both Warm and Cold Dark Matter cosmologies. The age, metallicity, and evolution of the stellar populations of the simulated dwarf galaxies are studied in both cosmologies using semi-analytic models that include a variety of feedback prescriptions. We present our results and discuss their interpretation.

408.06 – The Dwarfs Beyond: The Stellar-to-Halo Mass Relation For New Low Mass Galaxies to z~1

Sarah Miller[1, 2]
1. University of California, Irvine, Irvine, CA, United States. 2. California Institute of Technology, Pasadena, CA, United States.

A number of recent challenges to the standard λ-CDM paradigm relate to discrepancies that arise in comparing the abundance and kinematics of dwarf galaxies in the Local Group with the predictions of numerical simulations. Such arguments rely heavily on the assumption that the Milky Way's satellite galaxies form a representative distribution in terms of their ratio of stellar-to-halo mass. To address this question, we present new, deep spectroscopy using DEIMOS on Keck for 82 low mass (10^7-10^9 M™) star-forming galaxies at intermediate redshift ($0.2<z<1$). For 50% of these we are able to determine resolved rotation curves using nebular emission lines and thereby secure dynamical masses. This allows us to construct the stellar mass Tully-Fisher relation to masses as low as 10^7 M™. Using scaling relations determined from weak lensing data, we convert this to a stellar-to-halo mass (SHM) relation for comparison with abundance matching predictions. We find a discrepancy between the propagated predictions from simulations compared to our observations, and suggest possible reasons for this as well as future tests that will be more effective.

408.07 – Dark Matter Density Profiles in Late-type Dwarfs from Stellar Kinematics

Joshua J. Adams[1], Joshua D. Simon[1], Maximilian Fabricius[2], Remco van den Bosch[3], Karl Gebhardt[4]
1. Observatories of the Carnegie Institution of Washington, Pasadena, CA, United States. 2. Max Planck Institute for Extraterrestrial Physics, Garching, Germany. 3. Max Planck Institute for Astronomy, Heidelberg, Germany. 4. University of Texas at Austin, Austin, TX, United States.

We present new constraints on the density profiles of dark matter (DM) halos in seven nearby, dwarf irregular galaxies from measurements of their integrated light stellar kinematics. Low mass galaxies are frequently observed by their gaseous kinematics to have constant density DM cores while N-body simulations instead predict a cuspy profile. This work builds on a pilot study where we found one galaxy, NGC 2976, to possess a cuspy DM halo when measured in the stars but a cored DM halo when measured in the gas. We now present an expanded data set of high resolution integral field spectroscopy on seven galaxies, with high enough S/N to measure the stellar and gas kinematics simultaneously. With these improved data, we explicate the cause of the discrepancy in NGC 2976 as triaxial structure that most strongly biases the modeling of the colder gas relative to the stars. Using both Jeans and Schwarzschild modeling on our full sample, we examine whether gas kinematics in general produce shallower density profiles than are derived from the stars. The larger sample shows that not all cores go away when measured with stellar kinematics and there remains a wide range of DM halo profiles between galaxies. Finally, we search for correlations of DM profile with stellar velocity anisotropy and chemical abundance gradients. Two popular mechanisms to explain cored DM halos are a warm DM component or feedback models which strongly couple the energy of supernovae into repeatedly driving out gas and dynamically heating the DM halos. We confront both models with our new constraints.

408.08 – Search for Line Features in Galaxy Clusters with the Fermi-LAT

Brandon Anderson[1]
1. University of Stockholm, Stockholm, Sweden.
Contributing teams: Fermi-LAT Collaboration

Indirect searches for dark matter (DM) focus on the products of its potential self-interaction or decay. Using gamma rays, which travel on straight paths, facilitates isolation (and combination) of sky regions with particularly high DM column density. This approach is often complicated by the presence of continuum foregrounds which must be disentangled from the DM signal. Unique spectral features, e.g. a monochromatic line, avoid the issue entirely, allowing unambiguous study of areas where we have little handle on conventional gamma production. Galaxy clusters, the largest gravitationally bound DM structures, fall squarely into this category. We present a search for gamma-ray line-like features originating from galaxy clusters in the Fermi-LAT data.

408.09 – Dark Matter and the Diffuse Galactic Ultraviolet Background

Joshua Tyler[1], James Overduin[1]
1. Towson University, Towson, MD, United States.

GALEX observations of the galactic ultraviolet background indicate that there is an excess not associated with known astrophysical sources. We investigate whether this excess could originate in processes involving dark matter in various forms, including the decay of massive neutrinos, annihilation and/or scattering of weakly-interacting massive particles (WIMPs), and axion-photon interconversion in the galactic magnetic field. There are problems with each of these mechanisms, leading us to conclude that the most conservative explanation at present likely involves scattering of starlight by dust. However, significant challenges also face any dust model if it is to account simultaneously for data in the ultraviolet and infrared.

409 – Debris Disks Around Young Stars and Planet Formation II

Oral Session – National Harbor 12 – 09 Jan 2014 10:00 am to 11:30 am

409.01 – Modeling Eccentric Debris Rings with SMACK: Collisions Change Everything

Marc J. Kuchner[1], Erika Nesvold[1]
1. NASA's GSFC, Greenbelt, MD, United States.

Resolved images of eccentric debris rings like the one around Fomalhaut can indicate the presence of embedded planets on eccentric orbits and constrain their masses. We use the new Superparticle Model/Algorithm for Collisions in Kuiper belts and debris disks (SMACK) to explore the effects of a planet with an eccentric orbit on a ring of planetesimals experiencing fragmenting collisions. We examine how well the assumption of collisional relaxation applies to rings like this around Fomalhaut and HR 4796. We analyze the effects of collisions on the size of the gap opened by the planet and compare our results with predictions from the theory of overlapping resonances. We also study the influence of planetary mass and eccentricity on asymmetric dust production in the ring, and consider the implications of these results for interpreting ALMA images in terms of pericenter glow.

409.02D – Filling in the Gaps: Illuminating Clearing Mechanisms in Transitional Circumstellar Disks

Katherine B. Follette[1], Laird M. Close[1], C. A. Grady[2], Jared Males[1]
1. University of Arizona, Tucson, AZ, United States. 2. Eureka Scientific, Oakland, CA, United States.
Contributing teams: MagAO team, SEEDS team

Transitional circumstellar disks, which host inner gaps or clearings, offer a window into the processes by which young stars lose their surrounding material. The precise physical mechanism(s) that leads to these clearings is widely debated. Photoevaporation, grain growth and, perhaps most interestingly, planet formation are among the leading hypotheses. The key to resolving this debate lies in very high resolution imaging of disk structures at multiple wavelengths. My thesis work has been focused on high-resolution adaptive optics imaging of transitional disks using near infrared scattered light and optical emission lines. I will present results suggesting that all three of the above processes – photoevaporation, grain growth and planet formation - may be at work in creating transitional disk clearings. Highlights of my thesis work include: the direct detection of an accreting object inside of a transitional disk gap at a separation of just 83mas, high resolution scattered light imaging of two transitional disks with perplexing properties, and the first silhouette disk detected at optical wavelengths with adaptive optics technology.

409.03 – [PZ99] J160421.7-213028, a transition disk with ring shaped dust accumulation

Ke Zhang[1], Andrea Isella[1], John M. Carpenter[1], Geoffrey A. Blake[1]
1. Caltech, Pasadena, CA, United States.

We present ALMA observations of the 880 µm continuum and CO J = 3-2 line emission from a transition disk around [PZ99] J160421.7-213028, a solar mass star in the nearby Upper Scorpius association. The observations reveal a low optical depth cavity in the dust continuum emission characterized by a radius of 79 AU. The dust detected inside the cavity is depleted by a factor of 10^{-2} compared to the edge of the outer disk. The CO emission in the inner disk is also depleted, but at a cavity radius only of 34AU. Our modeling shows that the dust surface density in the outer disk has an extremely steep profile, peaking at the dust truncation radius 79AU and decaying to 1/5 of the maximum value over a distance of only 20AU. This suggests that the majority of millimeter size grains are concentrated in a narrow ring region beyond the dust truncation radius, although the dust disk may extend to a much larger radius with a low surface density. We suggest that the large separation in the gas and dust cavity edges, as well as the high concentration of dust grains, can be explained by the dynamic interaction from unseen companions orbiting within 30AU from the central star, as suggested by theoretical models.

409.05 – Carbon but No CO? Circumstellar Gas Absorption in FUV Spectra of the Unusual 49 Ceti Debris Disk

Aki Roberge[1], Barry Welsh[2], Inga Kamp[3], C. A. Grady[1], Alycia J. Weinberger[4]
1. NASA GSFC, Greenbelt, MD, United States. 2. University of California Berkeley, Berkeley, CA, United States. 3. Kapteyn Institute , Groningen, Netherlands. 4. Carnegie DTM, Washington, DC, United States.

We present the first high-resolution HST-STIS FUV spectra of the nearby A1V star 49 Ceti. The system is famous for harboring a circumstellar disk that shows the dust properties of a debris disk, but the gas properties of a low-mass

protoplanetary disk. It is one of only two or three bona fide debris disks that show abundant sub-mm CO emission. Since the disk is nearly edge-on, the line of sight to the central star passes through the disk, permitting sensitive probes of the circumstellar gas with absorption spectroscopy. The spectra show many narrow circumstellar gas lines arising from several atomic species, including neutral carbon, a gas not seen in the diffuse interstellar medium. We present an accurate measurement of the line of sight column density, obtained from an unsaturated, spin-forbidden line. But carbon monoxide, the gas we expected to be most abundant, is not seen. We discuss possible explanations for this surprising observation, and the next steps in analyzing this rich dataset.

409.06 – Imitation is the sincerest form of flattery: is 49 Ceti the new Beta Pictoris?

Barry Welsh[1], Sharon L. Montgomery[2], Dylan Alu[2], Rosine Lallement[3]
1. UC, Berkeley, Pleasant Hill, CA, United States. 2. Clarion University, Clarion, PA, United States. 3. Paris Observatory, Meudon, France.

The young (40Myr) A1-type star 49 Ceti is thought to possess many of the same physical characteristics as Beta Pictoris, whose circumstellar gas and debris dust disks are the most well-studied of all exoplanet systems. As part of a campaign to monitor circumstellar activity in the gas disk(s) surrounding 49 Ceti, we present ground-based high spectral resolution observations (R ~ 60,000) of the visible circumstellar absorption lines recorded in conjunction with ultraviolet observations using the STIS instrument on HST in August 2013 (see presentation by Roberge et al at this conference). Our data, which spans a 6-week observational period, reveals significant variability in the properties of the circumstellar gas absorption which can be attributed to evaporating ionized Ca gas liberated by Kuiper Belt-like objects as they fall towards the central star. Similar behavior has been routinely observed towards Beta Pictoris. However, unlike Beta Pictoris we have observed anomalous behavior of the NaI and CaII IR-triplet lines in this extremely 'active" debris disk system of 49 Ceti.

409.07 – Hubble Space Telescope STIS Coronagraphy of WISE Debris Disk Candidates

Deborah Padgett[1], Karl R. Stapelfeldt[1,2], John E. Krist[2], Wilson M. Liu[3], David Leisawitz[1], Sergio Fajardo-Acosta[4], John H. Debes[5]
1. NASA/Goddard Space Flight Center, Greenbelt, MD, United States. 2. Jet Propulsion Laboratory, Pasadena, CA, United States. 3. NOAO, Tucson, AZ, United States. 4. IPAC, Pasadena, CA, United States. 5. STScI, Baltimore, MD, United States.

We report on an HST imaging program to search for debris disks in scattered light using the STIS coronagraph. The targets are 13 Hipparcos stars selected for robust levels of WISE 22 micron emission in excess of photospheric levels. These sources represent some of the closest and brightest of the large set of new WISE debris disk candidates (Padgett et al. 2013). Many of the sources appear as bare point spread functions with no extended nebulosity; two others are revealed as blends of bright stars with adjacent background star-forming galaxies. Debris disks were directly imaged in 5/13 targets, one of which is a marginal detection. Among these is an outstanding new edge-on system with diameter of 1000 AU and clear structural asymmetries suggestive of perturbations from planetary-mass companions. In this talk we will present HST images of these five new debris disk systems and discuss their characteristics.

410 – Evolution of Nearby Galaxies
Oral Session – Maryland Ballroom D – 09 Jan 2014 10:00 am to 11:30 am

410.01 – Galaxies as Clocks: the Radius -- Velocity Relationship of HI Rich Galaxies

Gerhardt Meurer[1], Danail Obreschkow[1], Daniel Hanish[2], Oiwei Wong[3], Zheng Zheng[4], Erwin WJG de Blok[5], David A. Thilker[4]

1. ICRAR / U Western Australia, Perth, WA, Australia. 2. Spitzer Science Center, Caltech, Pasadena, CA, United States. 3. CSIRO Astronomy & Space Science, Epping, NSW, Australia. 4. The Johns Hopkins University, Baltimore, MD, United States. 5. ASTRON, Dwingeloo, Netherlands.
Contributing teams: SINGG Team, SUNGG Team

We show that the outskirts of HI rich galaxies obey a linear radius (R) versus rotational velocity (Vrot) relationship. This means they behave like clocks: they have the same orbital time of ~800 Myr. The relationship is valid over the full range for which we have data - a factor of 30 from dwarf galaxies with R ~ 1 kpc and Vrot ~ 10 km/s to giant spirals with R = 30 kpc and Vrot = 300 km/s with an intrinsic scatter smaller than 40%. A linear R -- Vrot relationship is expected for Cold Dark Matter (CDM) dominated halos. The fact that the collapsed baryons of disk galaxies obey this relationship can be readily understood within the CDM paradigm. We show what is required for the situation to occur. The mean density within the outer radius is 3e-3 Msun/pc^3, requiring that the baryonic component of disk galaxies to have collapsed by a factor of ~40. We outline the practical uses of the relationship and the implications for galaxy evolution.

410.02D – High-Resolution HI and CO Observations of HIghMass Galaxies - High HI Mass, HI-rich Galaxies at z~0

Gregory Hallenbeck[1]
1. Cornell University, Ithaca, NY, United States.
Contributing teams: The ALFALFA Team

The HIghMass sample is a a group of 34 galaxies identified by the ALFALFA survey with both high HI mass ($M_{HI} > 10^{10}$ M™) and unusually high gas fraction (GF ? M_{HI} / M*; over half have GF > 1). Such galaxies are expected to be exceptionally rare. Have these galaxies recently acquired their gas, but have not yet been able to process it into stars? Or has this gas reservoir existed for a long time, and kept from forming stars by unusually high dark matter halo spin parameters? I present high-resolution HI and CO observations for a subset of these galaxies, and consider gas kinematics, stability, and inferred dark matter halo properties. The explanations for the current state of these galaxies are revealed to span a wide range of parameter space. For example, the HI in UGC 9037 is rapidly falling towards the center (v_{infall} ? 40 km s^{-1}) which should soon fuel a major episode of star formation. Conversely, the HI in UGC 12506 is rapidly rotating and of low surface density, suggestive of a high spin parameter. This work has been supported by NSF-AST-0606007 and AST-1107390, grants from the Brinson Foundation, and a Student Observing Support award from NRAO.

410.03 – A Hard X-ray View of Starburst Galaxies with NuSTAR

Ann E. Hornschemeier[1, 2], Daniel R. Wik[1], Bret Lehmer[2, 1], Andrew Ptak[1, 2], Vallia Antoniou[3], Megan Argo[4], Keith Bechtol[5], Fiona Harrison[6], Roman Krivonos[7], Jean-Christophe Leyder[1], Tom Maccarone[8], Daniel Stern[9], Tonia M. Venters[1], Mihoko Yukita[2, 1], Andreas Zezas[3], William Zhang[1]
1. NASA GSFC, Greenbelt, MD, United States. 2. Johns Hopkins University, Baltimore, MD, United States. 3. Smithsonian Astrophysical Observatory, Cambridge, MA, United States. 4. ASTRON, Dwingeloo, Netherlands. 5. Kavli Institute for Cosmological Physics, Chicago, IL, United States. 6. Caltech, Pasadena, CA, United States. 7. UC Berkeley, Berkeley, CA, United States. 8. Texas Tech University, Lubbock, TX, United States. 9. NASA JPL, Pasadena, CA, United States.
Contributing teams: NuSTAR Team

Six nearby starburst galaxies are being observed jointly with NuSTAR and soft X-ray imaging telescopes Chandra and XMM-Newton. These observations are providing crucial new input on what dominates the hard X-ray emission from star-forming galaxies, including the balance between accretion onto supermassive black holes and that onto stellar-mass black holes and neutron stars. We highlight our recently published results on the nuclear region of NGC 253 (Lehmer et al. 2013) which demonstrated that the hard X-ray emission from the galaxy is dominated by X-ray binaries (stellar mass black holes and neutron stars) rather than an accreting supermassive black hole. We describe the NuSTAR, Chandra and XMM-Newton observations of the two other galaxies (M83 and Arp 299) that have been recently completed as well as plans for the remaining three galaxies. These plans will be of interest to the wider community due to the anticipated opportunity to

propose for NuSTAR observing time through a Guest Observer program.

410.04 – Starburst Galaxy NGC 253 in a Hard (X-ray) Light: Resolving its Emission with NuSTAR

Daniel R. Wik[1,2], Bret Lehmer[2,1], Mihoko Yukita[2,1], Ann E. Hornschemeier[1,2], Andrew Ptak[1,2], Andreas Zezas[3], Keith Bechtol[4], Tonia M. Venters[1], Megan Argo[5], Vallia Antoniou[3], Fiona Harrison[6], Roman Krivonos[7], Jean-Christophe Leyder[1], Thomas J. Maccarone[8], Daniel Stern[9], William Zhang[1]
1. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 2. Johns Hopkins University, Baltimore, MD, United States. 3. Smithsonian Astrophysical Observatory, Cambridge, MA, United States. 4. Kavli Institute for Cosmological Physics, Chicago, IL, United States. 5. ASTRON, Dwingeloo, Netherlands. 6. Caltech, Pasadena, CA, United States. 7. UC Berkeley, Berkeley, CA, United States. 8. Texas Tech University, Lubbock, TX, United States. 9. NASA JPL, Pasadena, CA, United States.
Contributing teams: NuSTAR Team

We present the latest results from simultaneous NuSTAR, Chandra, and VLBA monitoring of the X-ray binary population and diffuse emission in the local starburst galaxy NGC 253. Focusing on the combined NuSTAR dataset, comprised of three ~165 ks observational periods, we spatially characterize the sources of hard X-ray (E > 10 keV) emission in this galaxy for the first time. We detect >10 distinct sources in energy bands up to 25 keV, which consist mostly of intermediate state high-mass X-ray binaries (HMXBs), although the hardest (E > 12 keV) emission is dominated by two ultraluminous X-ray Sources (ULXs). The global X-ray emission falls steeply (photon index >~ 3), consistent with that of ULX spectra, and no significant excess above backgrounds is detected at E > 30 keV. A prominent diffuse inverse Compton component, as predicted in leptonic models meant to describe Fermi and HESS gamma-ray emission from NGC 253, is thus disfavored. However, even with NuSTAR's unprecedented spatial resolution and low background, we are unable to fully exclude leptonic models at this time, although we do constrain their acceptable parameters.

410.05D – The Dynamics and Cold Gas Content of Luminous Infrared Galaxies in the Local Universe

George C. Privon[1]
1. University of Virginia, Charlottesville, VA, United States.

Many of the most luminous galaxies in the local universe are understood to be the product of mergers and interactions between disk galaxies. These encounters trigger enhanced star formation and accretion onto supermassive black holes; the bulk of which is hidden behind significant extinction from dust. Dynamical simulations matched to individual systems can provide great insight into the merger-driven activity by placing objects on a dynamically-determined merger timeline and by enabling follow-up hydrodynamic simulations which can be used to compare simulations directly with observations. New dynamical models will be presented for luminous infrared galaxies drawn from the Great Observatories All-sky LIRG survey, along with a dynamically-motivated merger stage classification system; these are facilitating a detailed comparison of simulated and observed properties of star formation. New observations of the cold ISM in these systems will also be shown, investigating the influence of AGN activity on tracers of high density (> 10^5 cm^-3) molecular gas.

411 – Extrasolar Planet Detection - Ground-Based Observations

Oral Session – Maryland Ballroom A – 09 Jan 2014 10:00 am to 11:30 am

411.01D – Results and Lessons Learned From the KELT-North Wide-angle Transit Survey of Bright Stars

Thomas G. Beatty[1]

1. Ohio State University, Columbus, OH, United States.

Since 2006, the KELT-North transit survey has been collecting wide-angle precision photometry for 20% of the sky. This gave us the unique opportunity to conduct a statistically controlled and rigorous search for transiting planets among the 220,000 dwarfs stars targeted by the survey over 6 years. To date, we have detected over 18 transiting hot Jupiters, several of which have been new discoveries. Based on my previous work on theoretical transit survey statistics and yields, we consciously designed the lightcurve reduction and candidate selection process to be statistically robust and effective. I will discuss the process behind our candidate selection process, the lessons learned from operating the survey, highlights from KELT's first detections, and some initial results from the exoplanet statistics determined by the survey. Many of the considerations that went into KELT's operations will be directly relevant to the upcoming TESS survey mission, which will be searching the same stellar population with the same field of view for transiting planets.

411.02 – Observation of a Transit Ingress of HD 80606b in Polarized Light

Sloane Wiktorowicz[1], Gregory P. Laughlin[1]

1. University of California, Santa Cruz, Santa Cruz, CA, United States.

Using the POLISH2 polarimeter at the Lick Observatory 3-m telescope, we present tentative observations of a single transit ingress of an exoplanet in polarized light. In contrast to photometric transits, whose peak signal occurs at midtransit due to occultation of the brightest region of the stellar disk, polarimetric transits provide a signal upon ingress and egress due to occultation of the polarized stellar limb. Limb polarization, the bright corollary to limb darkening, arises from the 90 degree scattering angle and low optical depth (and hence single scattering) experienced by photons scattered toward the observer from the stellar limb. Theoretically, the amplitude of a polarimetric transit should be caused by the exoplanetary to stellar radius ratio and the strength and width of the stellar limb polarization profile, which depends on the scattering to total opacity ratio at the stellar limb. While the limb-crossing time is roughly one-half hour for hot Jupiters on circular orbits, the unique geometry of the HD 80606b orbit provides a limb-crossing time of nearly three hours, which makes it the best candidate for observation of such an effect. The amplitude of the observed signal is roughly 0.1% in B band, which is an order of magnitude larger than expected for a sunlike star. Therefore, further observations are required to conclusively detect a polarimetric transit. Occultation of the stellar limb between first and second contacts rotates the position angle of net polarization by +5 +/- 11 degrees. Polarization position angle and Spitzer-derived impact parameter constrain the longitude of the ascending node of the HD 80606b orbit to be (-19.02 or +160.98) +/- 0.45 degrees. Given the HD 80607 position angle of 88.5 degrees with respect to HD 80606, the HD 80606b orbit is therefore nearly orthogonal to the instantaneous vector joining HD 80606 and its common proper companion HD 80607. This work is supported by a NExScI Sagan Fellowship and UCO/Lick Observatory.

411.03 – Limits on Stellar Companions to Exoplanet Host Stars With Eccentric Planets

Stephen R. Kane[1], Steve B. Howell[2], Elliott Horch[3], David R. Ciardi[4], Andrew Howard[5], Ying Feng[6], Jason Wright[6]

1. San Francisco State University, San Francisco, CA, United States. 2. NASA Ames Research Center, Moffett Field, CA, United States. 3. Southern Connecticut State University, New Haven, CT, United States. 4. California Institute of Technology, Pasadena, CA, United States. 5. University of Hawaii, Honolulu, HI, United States. 6. Pennsylvania State University, University Park, PA, United States.

Though there are now many hundreds of confirmed exoplanets known, the binarity of exoplanet host stars is not well understood. This is particularly true of host stars which harbor a giant planet in a highly eccentric orbit since these are more likely to have had a dramatic dynamical history which transferred angular momentum to the planet. Here we present observations of four exoplanet host stars which utilize the excellent resolving power of the Differential Speckle Survey Instrument (DSSI) on Gemini North. Two of the stars are giants and two are dwarfs. Each star is host to a giant planet with an orbital eccentricity > 0.5 and whose radial velocity data contain a trend in the residuals to the Keplerian orbit fit. These observations rule out stellar companions 4 magnitudes fainter than the host star at passbands of 692nm and 880nm. The resolution and field-of-view of the instrument result in exclusion radii of 0.6-30 AU. We combine these data with Keplerian orbital solutions to investigate the source of the radial velocity trends. These results place dynamical constraints on the source of the planet's eccentricities, constraints on additional planetary companions, and informs the known distribution of

multiplicity amongst exoplanet host stars.

411.04 – Search for Magnetospheric Radio Emissions from Upsilon Andromeda

Daniel Winterhalter[1], Walid A. Majid[1], Mary Knapp[2], Ishwar Chandra[3]
1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, United States. 2. Massachusetts Institute of Technology, Cambridge, MA, United States. 3. National Center for Radio Astrophysics, Pune, Maharashtra, India.

Using the 150 MHz receivers of the Giant Meterwave Radiotelescope (GMRT) in India, we have searched for radio emissions from Upsilon Andromeda (UpsAnd). GMRT offers great sensitivity and aperture in this frequency range. Calibrations with GMRT at 150 MHz have confirmed the noise floor to be a few mJy over a 5 MHz bandwidth. The noise floor is well below the expected flux levels from the target. The first observation run showed promising but inconclusive results, reported on elsewhere. We have now repeated the observations and are in the process of analyzing the data. In this paper we will present the results of the analysis showing radio maps and dynamic spectra from the UpsAnd system.

412 – Galaxy Clusters in the X-rays
Oral Session – National Harbor 5 - 09 Jan 2014 10:00 am to 11:30 am

412.01 – Some Like It Hot: Linking Diffuse X-ray Luminosity, Baryonic Mass, and Star Formation Rate in Compact Groups of Galaxies

Tyler D. Desjardins[1], Sarah Gallagher[1], Ann E. Hornschemeier[2], John S. Mulchaey[3], Lisa May Walker[4], W. N. Brandt[5], Jane C. Charlton[5], Kelsey E. Johnson[4], Panayiotis Tzanavaris[2, 6]
1. Department of Physics and Astronomy, The University of Western Ontario, London, ON, Canada. 2. Laboratory for X-ray Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, MD, United States. 3. Carnegie Observatories, Pasadena, CA, United States. 4. Department of Astronomy, University of Virginia, Charlottesville, VA, United States. 5. Department of Astronomy and Astrophysics, The Pennsylvania State University, University Park, PA, United States. 6. Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, MD, United States.

Compact groups of galaxies (CGs) are ideal laboratories in which to study the effects of environmentally-driven galaxy evolution due to their high galaxy number densities and low velocity dispersions, which cause frequent and prolonged galaxy-galaxy interactions. In our study to better understand the origin and properties of hot gas in poor systems of galaxies, we present an analysis of the diffuse X-ray emission in a sample of 19 CGs observed with the Chandra X-Ray Observatory. Our analysis shows that the hottest, most X-ray luminous CGs agree well with the galaxy cluster X-ray scaling relations, even in CGs where the hot gas is clearly associated with the brightest galaxy. Using Spitzer photometry, we compute stellar masses and combine them with HI masses from the literature to find that high-baryonic-mass CGs are often X-ray luminous, while lower-mass CGs only sometimes exhibit faint X-ray emission attributed to star formation. We also use a new physically motivated definition of fossil groups (evolved galaxy groups where most of the mass is concentrated within a single galaxy) to investigate the hot gas properties of three compact fossil systems in our sample. In addition, we find that the most X-ray luminous CGs have the lowest star formation rates, likely because the cold gas has been exhausted in star formation, heated to X-ray temperatures, or removed from the galaxies by ram-pressure stripping. Finally, the optical colors that trace the recent star formation histories of the most massive group galaxies do not correlate with the X-ray luminosities of the CGs, indicating that perhaps the current state of the X-ray halos is not dependent on the recent assembly of stellar mass in the most massive galaxies. This work has been supported by the Natural Science and Engineering Research Council of Canada, the Ontario Early Researcher Award Program, and NASA.

412.02 – X-ray scaling relations in Compact Group Galaxies: Compact Object Populations with Chandra

Panayiotis Tzanavaris[1, 2], W. N. Brandt[4], Kelsey E. Johnson[5], Jane C. Charlton[4], Sarah Gallagher[3], Tyler D. Desjardins[3], Laura Lenkic[3]
1. NASA Goddard Space Flight Center, Greenelt, MD, United States. 2. Johns Hopkins University, Baltimore, MD, United States. 3. University of Western Ontario, London, ON, Canada. 4. The Pennsylvania State University, University Park, PA, United States. 5. University of Virginia, Charlottesville, VA, United States.

We report on the latest results from an on-going campaign to understand nuclear and accreting binary activity, as well as diffuse emission, in compact groups (CGs) of galaxies. Using multi-wavelength data for a sample of 19 CGs, we have measured star formation rates (SFRs) and stellar masses ($M*$). Using Chandra data for this sample, we have detected X-ray point sources (both nuclear and non-nuclear), as well as X-ray diffuse emission. We have thus achieved a detailed characterization of the X-ray data, which allows us, for the first time, to systematically explore the form of the X-ray scaling relations between, on the one hand, point-source X-ray luminosity, L_X, due to X-ray binary populations, and, on the other hand, SFR and $M*$ in this unique extragalactic environment. We compare the L_X-SFR-$M*$ correlation in CGs to (1) the well established correlation for the general extragalactic X-ray binary population, and (2) the L_X vs. SFR results for Ultraviolet-Luminous Galaxies (UVLGs). Both CG galaxies and UVLGs are earlier Universe analogs, allowing us to explore L_X-SFR-$M*$ evolution as a function of environment and cosmic time.

412.03D – A Comprehensive Study of the Outskirts of Galaxy Clusters

Jithin V. George[1], Richard Mushotzky[1], Eric D. Miller[2]
1. University of Maryland, Seabrook, MD, United States. 2. MIT, Cambridge, MA, United States.

Galaxy clusters are the largest gravitationally bound structures in the universe and thus provide the best opportunity to study cosmology at work. Their outskirts, regions close to the virial radius, are challenging to study, yet could aid in our understanding of cluster growth, structure and mass. We show results from a program to constrain the properties of the outer intra-cluster medium in a sample of galaxy clusters, making use the strengths of the three complementary X-ray

observatories: Suzaku which has a low and stable background, XMM-Newton which has a very high sensitivity, and Chandra which provides good spatial resolution. The sample comprises ten mostly relaxed clusters at z~0.1-0.2 with full azimuthal coverage to beyond r200. Here we report results obtained from a subsample of clusters. We are able to measure diffuse X-ray emission well beyond r200. Our results suggest that the ICM is not in hydrostatic equilibrium in the outskirts of these clusters, and we see evidence for azimuthal variations in temperature and surface brightness. We also present the density, entropy and baryonic function profiles for each of these clusters.

412.04 – Probing X-Ray Mass-Temperature Relation and Gas Mass Fraction with A Chandra Sample of 350 Galaxy Clusters and Groups out to z $\simeq$ 1.4

Jingying Wang[1]
1. Shanghai Jiao Tong University, Shanghai, China.

Mass-temperature relation of galaxy clusters and groups is an important indicator for examining our understanding of the evolution and thermal history of such systems. We present a systematic analysis on the largest sample so far, which consists of more than 300 clusters and groups from the Chandra archival data. We show that the mass-temperature relation of the high- and low-mass parts of the sample can be described with power-law relations with different slopes. We also find that there is a clear trend for cooler systems to have a smaller mass fraction of X-ray emitting gas, which is evident within r500. Both phenomena demonstrate that the effects of energy injection are more pronounced in less massive (i.e., cooler) systems.

412.05 – Joint Constraints on Concentration, Slope, and Nonthermal Pressure Support in X-ray and Weak Lensing Observations of Galaxy Clusters

Andisheh Mahdavi[1], Henk Hoekstra[2], Arif Babul[3], Angela Berti[1]
1. San Francisco State University, San Francisco, CA, United States. 2. Sterrewacht Leiden, Amsterdam, Netherlands. 3. University of Victoria, Victoria, BC, Canada.

We use the Joint Analysis of Cluster Observations (JACO) codebase to derive independent constraints on the concentration and slope of the dark matter profile in the CCCP sample of 50 rich nearby galaxy clusters. We find that relaxed clusters tend to have consistent X-ray and lensing derived concentrations, while unrelaxed clusters tend to disagree on these key dark matter parameters. In general, the weak lensing data are closer to cosmologically predicted mass-concentration relations than are X-ray derived values. Finally, a model of non-thermal pressure support derived from N-body simulation is fit jointly to these data, and yields useful constraints on deviations from hydrostatic equilibrium near r500.

412.06 – Quantifying Substructure Measures In X-ray Images of Galaxy Cluster Mergers With SLAM

Marios Chatzikos[1], Craig L. Sarazin[2], Brian W. O'Shea[3]
1. Univ. of Kentucky, Lexington, KY, United States. 2. University of Virginia, Charlottesville, VA, United States. 3. Michigan State University, East Lansing, MI, United States.

I use the Simulation Library of Astrophysical galaxy cluster Mergers (SLAM) database to quantify the effects of mergers on X-ray observables. SLAM consists of a set of 156 adiabatic simulations of binary galaxy cluster mergers, that covers 2 orders of magnitude in the mass of the primary cluster, four values for the mass contrast, and four values for the angular momentum of the collision. In this talk I describe results on substructure measures obtained for various viewing angles. I have quantified the substructure in X-ray images using both center shifts and power ratios. Mergers of intermediate mass contrasts produce substructure signals that can persist in X-ray images for at least 1-2 sound crossing times. The amplitude of both measures depends strongly on the initial mass contrast. The measures for major mergers (mass contrast less than 3) appear to depend on the system mass, while for minor mergers (mass contrast between 3 and 10) they are generally independent of the system mass. Neither measure reflects the true dynamical state of the system closely, although the center shifts appear to be a better proxy. Comparisons with the virial and hydrostatic disequilibrium parameters reveal that there is no value of either substructure measure that unambiguously distinguishes merging from relaxing systems. Implications for SZE observations will also be discussed.

413 – Public Policy
Oral Session – National Harbor 2 – 09 Jan 2014 10:00 am to 11:30 am

413.02 – An Astronomer's View of Climate Change

Donald C. Morton[1]
1. National Research Council of Canada, Herzberg Astronomy and Astrophysics Programs, Victoria, BC, Canada.

There are several astronomical effects that could be important for understanding climate changes such as the ice ages, the Medieval Maximum, the Little Ice Age, the 20th century temperature rise and the small decrease during the past 15 years. These effects include variations in the sun's luminosity, periodic changes in the earth's orbital parameters, the sun's orbit around our galaxy, the solar wind, the variability of solar activity and the anticorrelation of the galactic cosmic ray flux with that activity. With the publication of the Fifth Assessment Report to the Intergoverment Panel on Climate Change, it is useful to review these effects and the extent to which that report and previoius ones have recognized them. This paper also discusses recent trends in solar activity and global temperatures and compares the latter with the predictions of climate models.

413.03 – The IAU Office of Astronomy Development

Jean-Christophe Mauduit[1], Kevin Govender[1]
1. International Astronomical Union, Office of Astronomy for Development, Cape Town, Western Cape, South Africa.

The International Astronomical Union (IAU), the largest body of professional astronomers in the world, has set up the Office of Astronomy for Development (OAD) in partnership with the South African National Research Foundation (NRF). The OAD is located at the South African Astronomical Observatory (SAAO) in Cape Town. Its mission is to realise the IAU's Strategic Plan, which aims to use astronomy as a tool for development. It focuses on the following three main areas: "Universities and Research", "Children and Schools" and "Public Outreach". Eighteen projects worldwide have been funded for 2013 and are currently under way. More will be starting in 2014. The OAD is also setting up regional nodes and language expertise centres around the world. This presentation will describe the ongoing activities of the OAD and plans for the future.

413.04 – Dark Skies Yuma: An NOAO and APS Program on Light Pollution Education

Stephen M. Pompea[1], Constance E. Walker[1], Chuck Dugan[1], William T. Roddy[2], Mark Newhouse[1]
1. NOAO, Tucson, AZ, United States. 2. University of Arizona, Tucson, AZ, United States.

Fifteen Yuma 6th grade teachers participated in a dark skies preservation and energy conservation professional development and classroom program delivered by NOAO during 2013. Two teacher professional development workshops and a culminating Family Science Night for students to display projects occurred. Between workshops, support was provided through real-time video conferencing using iPads. In the first workshop the teachers were provided foundational, scaffolded activities in accordance with STEM standards, resource materials in kits to facilitate the activities, and firsthand experiences in doing the activities with students. The second workshop focused on dark skies and energy education projects done in March and April. Teachers received training on how to work with classes on outdoor lighting in their communities and distinguish between energy efficient and wasteful outdoor lighting. In May, 2013, student projects were presented to parents and the school community as part of a Family Science Night and served as a form of authentic assessment of the students' work. Participants will take away from this presentation new techniques for using iPads to sustain a community of educators as well as immersing them (and in turn, their students) in Project Based Learning after a scaffolded sequence of activities on dark skies preservation and energy conservation. View a video of the Family Science Night event at http://www.noao.edu/education/video/Dark-Skies-A-Night-of-Light/.

413.05 – Progress in Dark Sky Protection in Southern Arizona

Richard F. Green[1, 2], Lori Allen[2, 11], Elizabeth M. Alvarez Del Castillo[3], Daniel K. Brocious[4], Christopher J. Corbally[5], Donald R. Davis[6], Emilio E. Falco[4], Paul Gabor[5], Jeffrey C. Hall[7], Buell Jannuzi[1, 13], Stephen M. Larson[8, 13], Kenneth J. Mighell[11], Craig Nance[9, 1], Paul D. Shankland[10], Constance E. Walker[11], G. Grant Williams[12, 1], Dennis F. Zaritsky[1]
1. Steward Observatory, Tucson, AZ, United States. 2. Kitt Peak National Observatory, Tucson, AZ, United States. 3. AdC Consulting, Tucson, AZ, United States. 4. Smithsonian Astrophysical Observatory, Tucson, AZ, United States. 5. Vatican Observatory, Tucson, AZ, United States. 6.

Planetary Sciences Institute, Tucson, AZ, United States. 7. Lowell Observatory, Flagstaff, AZ, United States. 8. Lunar & Plantetary Laboratory, Tucson, AZ, United States. 9. Mt. Graham International Observatory, Tucson, AZ, United States. 10. U.S. Naval Observatory, Flagstaff, AZ, United States. 11. National Optical Astronomy Observatory, Tucson, AZ, United States. 12. MMT Observatory, Tucson, AZ, United States. 13. University of Arizona, Tucson, AZ, United States.

Arizona has many observatories dedicated to scientific research and a rapidly growing population. Continuous interaction with governmental entities and education of the public are required to take advantage of the good intentions of lighting control ordinances in place around the state. We give several recent examples of active engagement of observatories: * Interaction of Mt. Graham International Observatory with the State prison and major copper mine. * Interaction of Smithsonian Astrophysical Observatory, acting on behalf of MMT Observatory and Steward Observatory, with the US Forest Service on the prospects of developing the Rosemont Copper Mine * Defense of the Outdoor Lighting and Sign Codes in Pima County and the City of Tucson * Coordinated observatory approach to statewide issues, including the establishment of radial zones of protection from LED billboards around observatory sites.

413.06 – Recent Local and State Action in Arizona to Maintain Sky Quality

Jeffrey C. Hall[1], Paul D. Shankland[2], Richard F. Green[3], Buell Jannuzi[3]
1. Lowell Obs., Flagstaff, AZ, United States. 2. United States Naval Observatory, Flagstaff, AZ, United States. 3. Steward Observatory, Tucson, AZ, United States.

The large number of observatories in Arizona has led to the development of a number of lighting control ordinances around the state, some quite strict. Several factors are now contributing to an increased need for active effort at the local, County, and State levels in maintaining the quality of these codes; these factors include an expansion of competing interests in the state, the increasing use of LED lighting, and the potential for major new investments through projects such as the Cherenkov Telescope Array (CTA) and enhancements to the Navy Precision Optical Interferometer. I will review recent strategies Arizona's observatories have used to effect maintenance of ordinances and preserve sky quality; cases include (1) a statewide effort in 2012 to curb a proliferation of electronic billboards and (2) engagement of a broad group of local, County, and State officials, as well as individuals from the private sector, in support of projects like CTA, including awareness of and support for dark-sky preservation.

413.07 – IAU Commission 50 on Astronomical Site Protection

Constance E. Walker[1], Richard F. Green[2]
1. NOAO, Tucson, AZ, United States. 2. Univ. of Arizona, Tucson, AZ, United States.

Increasing world population and activity in remote areas are leading to encroachment of artificial noise background into the sky in both optical and radio wavelengths. IAU Commission 50 is working to engage astronomers in countries that host, support, or use ground-based observing facilities on the urgency of this issue through informational meetings, outreach, and provision of content for presentations. We encourage and endorse local initiatives and represent the IAU on site protection issues to agencies like URSI and UNESCO. IAU C50 also engages with the lighting industry through their professional societies, CIE and IESNA. The presentation gives examples of recent activity and links to material valuable for protection of US sites.

414 –

Special Session – Potomac Ballroom A – 09 Jan 2014 10:00 am to 11:30 am

Over the years, NASA has invested heavily in the development and execution of an extensive array of space astrophysics missions that span the electromagnetic spectrum. The magnitude and scope of the archival data from those missions enables science that transcends traditional wavelength regimes and allows researchers to answer questions that would be difficult, if not impossible, to address through an individual observing program. To capitalize on this invaluable asset and enhance the scientific return on NASA mission investments, the Astrophysics Data Analysis Program (ADAP) provides support for investigations whose focus is on the analysis of archival data from NASA space astrophysics missions. This session highlights recent research results in the general area of galactic astrophysics from investigators supported under the ADAP Program.

415 – Stellar Evolution I

Oral Session – Potomac Ballroom C – 09 Jan 2014 10:00 am to 11:30 am

415.01D – Stellar Ages from Rotation and Asteroseismology

Courtney R. Epstein[1]
1. Ohio State University, Columbus, OH, United States.

Determining individual ages for large populations of field stars will enhance our understanding of the timescale for Galactic formation, evolution, and enrichment. Measuring ages for many field stars using traditional techniques is difficult and requires new, distance-independent methods. To further this goal, I have worked on calibrating two important age-diagnostics: rotation and asteroseismology. Because stellar winds in low-mass main-sequence stars cause them to spin down with time, the rotation-mass-age relationship may be treated like a clock. I will describe how I use published rotation data in open clusters to constrain models of angular momentum loss. I find that the precision of rotation-based ages is limited by the intrinsic spread in rotation rates among rapid rotators and differential rotation for hotter stars. Rotation-based ages are shown to outperform parallax-based ages for these slowly evolving, low-mass stars. For red giants, ages may be determined by combining mass and composition measurements. Kepler has detected solar-like oscillations in thousands of red giants and those oscillations encode information about the interior structure and fundamental stellar properties, like mass and radius. The SDSS-III APOGEE survey is obtaining spectra of those giants and measuring detailed chemical abundances that, when combined with asteroseismic masses, will provide reliable ages. Toward that goal, I am calibrating the asteroseismic mass scale in the low-metallicity regime using members of the Galactic halo and thick disk. I will describe this work and other updates from the APOGEE-Kepler collaboration.

415.02 – Characterization of Kepler Exoplanet Host Stars

Steve B. Howell[1], Mark Everett[2], David R. Ciardi[3], David Silva[2], Paula Szkody[4]
1. NASA ARC, Moffett Field, CA, United States. 2. NOAO, tucson, AZ, United States. 3. NASA Exoplanet Archive, pasadena, CA, United States. 4. University of Washington, seattle, WA, United States.

Using a sample of 220 Exoplanet host stars in the Kepler field for which spectroscopic properties have been determined, we examine their spatial, physical, and time variable properties. Covering effective temperatures from 4670K to 6400K (K4 to F4) and masses from 0.7 to 1.4 M-sun, this sample represents host stars covering the entire Kepler field of view. The majority of the host stars contain one or more Earth-sized exoplanet and range in log g from 4.0 to 4.7 and [Fe/H] from -02.4 to +0.3. Using Yale-Yonsei isochrone fits and photometric information form the Howell-Everett UBV survey of the Kepler field, we examine a complete set of parameters for these stars including their likely residence in the thin or thick disk of the Galaxy. the variability of this sample, in terms of time sale and amplitude, is examined as well.

415.03D – Variability of Elemental Abundances in the Local Neighborhood and its Effect on Planetary Systems

Michael D. Pagano[1], Patrick A. Young[1]
1. Arizona State University, Tempe, AZ, United States.

Does a true range of elemental compositions amongst local stars exist? How does this variation effect possible planetary systems around these stars? Through calculating and analyzing the variation in elemental abundances of nearby stars, the actual range in stellar abundances can be determined using statistical methods. This research emphasizes the improvement needed within the field of stellar abundance determination, both by the ease of measuring and by standardization. An intrinsic variation has been found to exist for almost all of the elements studied by most abundance-finding groups. Specifically, this research determines abundances for our own set of F, G, and K stars (~400 stars) from spectroscopic planet hunting surveys for 27 elements, including: C, O, Na, Mg, Al, Si, S, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Y, Zr, Mo, Ba, La, Ce, Nd, Eu, and Hf, where some elements are not measured in all stars. Abundances of the elements in many known exosolar planet host stars are calculated for the purpose of hypothesizing new ways to visualize how stellar abundances could affect planetary systems, planetary formation, and mineralogy. For example, the emphasis on the unusual stellar abundances of Tau Ceti is being heavily analyzed. Tau Ceti is theorized to have 5 planets of Super-Earth masses orbiting in near habitable zone distances(Tuomi, M. et al. 2013). Spectroscopic analysis finds that the Mg/Si ratio is extremely high (~2) for this star, which could lead to alterations in planetary properties. Tau Ceti's low metallicity and Oxygen abundance leads to changes in the location of the traditional habitable zone. In addition, the abundance results of a spectroscopic survey of around 400 stars will be presented. This is completed by observing mineralogical ratios, such as Mg/Si and C/O, as well as constructing other useful ratios for determining the effects of individual stellar abundances.

415.04D – Better Stars, Better Planets: Using Stellar Rotation to Refine Estimates of Stellar Parameters

Jennifer Van Saders[1]
1. The Ohio State University, Columbus, OH, United States.

Rotation is a fundamental property of all stars. Rotation periods are a strong function of age, evolutionary state, and mass for single stars on the main sequence (MS) and subgiant branch (SGB). These rates may differ by up to an order of magnitude when comparing hot or or young stars to cool or evolved stars. Because rotation depends sensitively on underlying stellar parameters that are challenging to measure, namely mass and age, measurements of rotation can be used to constrain and complement stellar parameters inferred through other means. This is particularly crucial in the case of transiting exoplanet host stars. We have produced models of stars with realistic angular momentum loss laws, both on the MS and SGB. Two important features of the rotation distribution are apparent: on the subgiant branch itself, rotation periods can differ by an order of magnitude between stars born above the Kraft break (6250 K) and those born below it. This allows one to infer both masses and radii on the SGB based on rotation. Secondly, subgiants born above the Kraft break can be rapidly rotating and masquerade as young stars in samples in which the luminosity or gravities are not well known. Therefore, when realistic populations of stars are considered, one cannot simply assume that rapid rotation is always an indication of youth. We provide examples with data from Kepler, among other sources, in which the addition of rotation information our understanding of the underlying stellar (and therefore planetary) distribution substantially. Implications for planet demographics are also discussed.

415.05 – Implementing New Semi-Convection and Overshooting Prescriptions in KEPLER

Justin Brown[1], Pascale Garaud[1], Stan E. Woosley[1]
1. University of California - Santa Cruz, Santa Cruz, CA, United States.

The processes of semi-convection and overshooting convection have been shown to have drastic impacts on the evolution of stars; in particular, the pre-supernova structure of massive stars depends strongly on the mixing prescription of semi-convection used in 1D stellar models. This has a significant impact on the properties of the supernova and the produced nucleosynthesis (Woosley & Heger 2002). There is currently little consensus on the most appropriate 1D models of semi-convection and overshooting convection, so we have implemented the physically-motivated semi-convection prescriptions from Wood, Garaud, & Stellmach (2013) and Moll, Garaud, & Stellmach (in preparation) and overshooting convection prescription from Rempel (2004) into KEPLER. We present the comparisons of these implementations with the previous semi-convection treatment from Langer, Fricke, & Sugimoto (1983) for a range of massive stars.

415.06 – In situ Ca and Mg abundancies in the stellar halo of the Galaxy

Emma Fernandez-Alvar[1], Carlos Allende-Prieto[1]
1. Instituto de Astrofísica de Canarias, La Laguna, Tenerife, Spain.

We still have a very limited knowledge about the formation of the early Milky Way. A line of research has focused on understanding the nature of the stellar halo, finding kinematical and chemical evidence of substructure. The existence of substructure is in line with the hierarchical formation scenario predicted by λCDM simulations for large galaxies such as ours. Studies based on high resolution spectroscopy have been limited to stars in the solar neighbourhood, and their conclusions rely on correlations between kinematics and chemistry. In this work, we have searched for halo stars in situ, using mid-resolution (R~2000) spectra included in the SDSS/SEGUE survey for stars at distances between 5 kpc and 100 kpc. We have analyzed a sample of stars with effective temperatures in the range $5800 < T_{eff} < 6300$ K, surface gravities between $0.0 < logg < 5.0$ dex and metallicities between $-2.0 < [Fe/H] < -0.4$ dex. We have derived Ca/Fe and Mg/Fe abundance ratios from the spectra and found clear correlations with metallicity and distance from the Galactic center.

416 – The Nuclear Spectroscopic Telescope Array (NuSTAR)

Special Session – Potomac Ballroom D – 09 Jan 2014 10:00 am to 11:30 am

The Nuclear Spectroscopic Telescope Array (NuSTAR), launched on 2012 June 13, is the first focussing hard X-ray mission in orbit. With approximately 10 times greater spatial resolution and more than 100 times greater sensitivity than previous missions in this energy band, NuSTAR has opened the high-energy sky to sensitive study. Over the first year of the mission, NuSTAR has undertaken a range of studies, from observations of energetic events towards the center of the Milky Way galaxy to detailed studies of distant supermassive black holes. During our Special Session we will describe the status and performance of NuSTAR, and present science results from the first 18 months in orbit.

416.01 – The Nuclear Spectroscopic Telescope Array (NuSTAR)

Daniel Stern[1]
1. JPL/ Caltech, Pasadena, CA, United States.
Contributing teams: NuSTAR Team

The Nuclear Spectroscopic Telescope Array (NuSTAR) mission, launched on 13 June 2012, is the first focusing high-energy X-ray telescope in orbit. NuSTAR operates in the band from 3 -- 79 keV, extending the sensitivity of far beyond the ~10 keV high-energy cutoff achieved by all previous focusing X-ray satellites. The inherently low-background associated with concentrating the X-ray light enables NuSTAR to probe the hard X-ray sky with a more than one-hundred-fold improvement in sensitivity over the collimated or coded-mask instruments of previous missions operating in this bandpass. In this talk I will provide an overview of the mission, briefly discuss the in-flight performance, and present some science highlights from the first 18 months in orbit.

416.02 – NuSTAR Observations of the Cassiopeia A Supernova Remnant

Brian Grefenstette[1]
1. California Institute of Technology, Pasadena, CA, United States.
Contributing teams: The NuSTAR Team

Young supernova remnants represent a unique laboratory for the study of supernova explosion dynamics and particle acceleration in the local universe. In the hard X-ray band probed by NuSTAR (3-79 keV), the continuum emission is thought to be dominated by synchrotron radiation from ~TeV electrons, while line emission at 68 and 78 keV is produced by the decay of radioactive 44Ti synthesized in the supernova explosion. With NuSTAR we can spatially resolve these hard X-ray components for the first time. Here we report on the results from deep NuSTAR observations (>1 Ms) of the young (~340 year old) supernova remnant Cassiopeia A.

416.03 – NuSTAR Reveals Intrinsically X-ray Weak Broad Absorption Line (BAL) Quasars

Stacy H. Teng[1] , W. N. Brandt[2], Bin Luo[2], Fiona Harrison[3]
1. NASA/GSFC, Greenbelt, MD, United States. 2. Penn State University, University Park, PA, United States. 3. Caltech, Pasadena, CA, United States.
Contributing teams: The NuSTAR Science Team

The Nuclear Spectroscopic Telescope Array (NuSTAR) is providing unprecedented sensitivity to the high energy extragalactic sky in the 5 - 79 keV band. NASA's newest X-ray observatory is revolutionizing our understanding of the obscured population of active galactic nuclei (AGN) in this energy range. NuSTAR's targeted obscured AGN program includes observations of famous, nearby obscured AGN, nearby ultraluminous infrared galaxies, BAL quasars, SDSS type-2 AGN and WISE-selected obscured AGN. Here, we highlight recent results on NuSTAR observations of three nearby BAL quasars (Mrk 231, PG 1004+130, and PG 1700+518) to determine whether the observed X-ray faintness is a result of intrinsic X-ray weakness or obscuration. Confirmation of intrinsically X-ray weak AGN in BAL quasars would have important consequences regarding the origin of BAL features and models of BAL winds.

416.04 – The NuSTAR Black Hole Spin Program

Dom Walton[1]
1. Caltech, Pasadena, CA, United States.
Contributing teams: The NuSTAR Team

Measurement of black hole spin has the potential to enhance our understanding in a wide variety of key astrophysical topics, including galaxy formation and the growth of supermassive black holes, supernova/GRB explosions, and relativistic jets. The best methods for measuring black hole spin currently available are anchored in X-ray spectroscopy, and ultimately rely on constraining the radius of the innermost stable circular orbit (ISCO), which relates directly to spin. Although such measurements are in their relative infancy, substantial progress has been made over the last few years. NuSTAR has

undertaken a major program, coordinated with XMM, Swift and Suzaku, to obtain the highest-quality broad band X-ray spectra from AGN and BH binaries to date, with the aim of obtaining spin constraints. The quality of the data not only allows us to make robust constraints, but also challenge the physical assumptions inherent in the relativistic reflection models primarily utilized for these measurements. We review the current status of this program, highlighting in particular some of the early observational results obtained.

416.05 – A first look at the distant high energy X-ray population with NuSTAR

Francesca M. Civano[1,2]
1. Dartmouth College, Cambridge, MA, United States. 2. SAO, Cambridge, MA, United States.
Contributing teams: the NuSTAR Team

The Nuclear Spectroscopic Telescope Array (NuSTAR), launched in June 2012, is opening the high energy X-ray sky for sensitive study for the first time. NuSTAR focusing X-ray optics are resolving the sources contributing to the peak of the X-ray background at >10 keV. To provide a sensitive census of this population, NuSTAR is performing an extragalactic survey, using a 3 tier approach: a very deep 200 ks, pencil-beam survey of the Extended Chandra Deep Field-South (ECDFS), a moderate depth 50 ks survey of the COSMOS field, and a shallow survey suing serendipitous sources detected in target local bright sources. In this talk, I will report on the first results from this survey, including now about 200 sources in the three fields combined. The NuSTAR sources are approximately 100 times fainter than those previously detected at >10 keV by Swift/BAT and have a very broad range in redshift and luminosity (z=0.02-3). The sources are characterized on the basis of their X-ray properties (hardness ratio and luminosity), optical spectroscopy and optical to mid -infrared spectral energy distributions.

417 – Young Stellar Objects I
Oral Session – National Harbor 4 – 09 Jan 2014 10:00 am to 11:30 am

417.01 – VLA and CARMA Observations of Binaries and Disks in the Protostellar Phase

John J. Tobin[1]
1. National Radio Astronomy Observatory, Charlottesville, VA, United States.

There has been much debate in recent years as to whether or not large disks form during the earliest phase of protostellar evolution, the Class 0 phase, with the implication that binaries cannot formvia disk fragmentation. There are now two examples of Class 0 disks discovered with the SMA and CARMA, but larger samples are needed for broader characterization of disks in the Class 0 phase. I will report results from a small CARMA survey of 10 Class 0 protostars in the Perseus molecular cloud at 80 AU spatial resolution and results from the VLA toward three protostars in Cepheus at 20 AU spatial resolution. The VLA observations find that two protostars have binary companions separated by 100 AU and CARMA follow-up of one source detects an apparent circumbinary disk. We suggest that these companions formed via disk fragmentation rather than forming at larger scales and migrating. These results have motivated us to pursue a large survey with the VLA that is observing every Class 0 and I protostar in the Perseus molecular cloud at resolutions up to 15 AU. This survey will place definitive constraints on where binaries are forming during the Class 0 phase and resolve protostellar disks. We will report early results from this survey if possible.

417.02 – Connecting diverse molecular cloud environments with nascent protostars in Orion

Amelia M. Stutz[2,1], S. Thomas Megeath[3], William J. Fischer[3], Babar Ali[6], Elise Furlan[7,6], John J. Tobin[4], Thomas Stanke[5], Thomas Henning[2], Oliver Krause[2], Manoj Puravankara[9], Mayra Osorio[8], Thomas Robitaille[2]
1. University of Arizona/Steward Observatory, Tucson, AZ, United States. 2. MPIA, Heidelberg, Germany. 3. University of Toledo, Toledo, OH, United States. 4. NRAO, Charlottesville, VA, United States. 5. ESO, Garching, Germany. 6. NHSC, Pasadena, CA, United States. 7. NOAO, Tucson, AZ, United States. 8. IAA/CSIC, Granada, Andalucia, Spain. 9. TIFR, Mumbai, India.
Contributing teams: HOPS team

Understanding how the gas environment within molecular clouds influences the properties of protostars is a key step towards understanding the physical factors that control star formation. We report on an analysis of the connection between molecular cloud environment and protostellar properties using the Herschel Orion Protostar Survey (HOPS), a large multi-observatory survey of protostars in the Orion molecular clouds. HOPS has produced well sampled 1 um to 870 um SEDs of over 300 protostars in the Orion molecular clouds using images and spectra from 2MASS, Spitzer, Herschel and APEX. Furthermore, the combination of APEX 870 um continuum observations with the HOPS/PACS 160 um data over the same area allows for a determination of the temperatures and column densities in the often filamentary dense gas surrounding the Orion protostars. Based on these data, we link the protostellar properties with their environmental properties. Utilizing the diverse environments present within the Orion molecular clouds, we show how the luminosity and spacing of protostars in Orion depends on the local gas column density. Furthermore, we report an unusual concentration of the youngest known protostars (the Herschel identified PBRS, PACS Bright Red Sources) in the Orion B cloud, and we discuss possible reasons for this concentration.

417.03 – YSOVAR: Infrared Reverberation Mapping of a Protoplanetary Disk

Huan Meng[1,2], Peter Plavchan[1], Tina Gueth[3], John R. Stauffer[4], Kevin Covey[5], Rachel L. Akeson[1], Sean J. Carey[4], John M. Carpenter[6], David R. Ciardi[1], Robert A. Gutermuth[7], Patrick M. Ogle[4], Luisa M. Rebull[4], Karl R. Stapelfeldt[8], Barbara Whitney[9], Maria Morales-Calderon[10], Alan Watson[11], Ann Marie Cody[1], George Rieke[2], Kevin M. Flaherty[2,12]
1. IPAC, Caltech, Pasadena, CA, United States. 2. University of Arizona, Tucson, AZ, United States. 3. New Mexico Institute of Mining and Technology, Socorro, NM, United States. 4. Spitzer Science Center, Pasadena, CA, United States. 5. Lowell Observatory, Flagstaff, AZ, United States. 6. Caltech, Pasadena, CA, United States. 7. University of Massachusetts, Amherst, MA, United States. 8. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 9. University of Wisconsin, Madison, Madison, WI, United States. 10. Centro de Astrobiología, Villanueva de la Canada, Madrid, Spain. 11. Universidad Nacional Autonoma de Mexico, Morelia, Michoacan, Mexico. 12. Wesleyan

University, Middletown, CT, United States.
Contributing teams: YSOVAR Collaboration

Theoretical models and spectroscopic observations of protoplanetary disks suggest the presence of an inner disk wall, in which dust is depleted by thermal vaporization and/or magnetospheric accretion. The size of the inner evacuated region is expected to be on a sub-AU scale that is unresolved by current adaptive optics imaging, though some constraints can be obtained by interferometric observations. Here we report the first detection of an inner disk wall around a Class I YSO in ? Ophiuchus, YLW 16B, by measuring the time lag between the near-infrared variations of partial protostellar radiation and the 4.5 μm response from the disk. The near-infrared time-series were obtained from four different ground-based telescopes, and the 4.5 μm time-series were simultaneously obtained with the Spitzer Space Telescope in staring mode. All times are corrected to barycentric dynamical time. Consistent and robust lags are detected in two nights with different data reduction methods. The time-series in H and K bands are synchronized while the 4.5 μm emission lags by ~60s, corresponding to a light travel time distance of ~0.2 AU. The accurate distance depends on the spectral contribution and geometry of the disk, which is difficult to ascertain due to the variability of the system.

417.04D – Signatures of disk structure from line profile variability

Stacie Powell[1], David W. Latham[2], Michael Irwin[1], Jerome Bouvier[3], Cathie Clarke[1], Stefano Facchini[1]
1. Institute of Astronomy, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom. 2. Harvard-Smithsonian CfA, Boston, MA, United States. 3. IPAG, Grenoble, France.

Despite the abundance of FU Orionis objects (FUors) in the solar neighborhood and the implied repetitive nature of this episodic accretion phenomenon in low-mass stars, the triggering mechanism within the disk, propagation from the disk to the wind and the implications of these outbursts on planet formation remain unclear. FUors are young stars where disk accretion increases from 10^{-7} to 10^{-4} M™ yr^{-1} within a decade, with a slow decline of over 100 years. These systems provide a unique opportunity to observe the inner disk photosphere in optical light. Previous observations of the prototype FU Orionis by Herbig et al. (2003) suggest that the wind and disk photospheric lines are modulated with periods of 14.54 and 3.54 days, respectively. We have re-observed the system at higher resolution with SOPHIE and TRES, by monitoring variations of optical line profiles over 21 nights in 2007 and 35 nights in 2012-13. We detect wind periods of 13 days and 10 days (present in the latter epoch only), which are manifested not only in blueshifted Hα absorption, as found previously, but also in redshifted emission of Hα and Hβ, as well as in blueshifted absorption of Na I D, Li I and Fe II λ5018. We discuss the potential configurations responsible for the two distinct wind modulations in this system. In addition the disk photospheric lines show periods of 3.6 and 3.2 days in 2007 and 2012-13, respectively. Remarkably, this implies variability mechanisms that are stable against shear over at least 15 years (>1000 orbits); we tentatively ascribe this to an orbiting hotspot in the disk. We have monitored the velocity shift of these periodic variations for the first time, which are confined to the blue wing of the line profiles and centered on velocities of -9 and -60 km s^{-1} in 2007 and 2013, respectively. We discuss the possibility of an embedded hot Jupiter precessing on an inclined orbit relative to the disk to explain the different velocities of the detected periodic signal between all three epochs. The first detection of a potential hot Jupiter in a FUor may provide significant merit to theories of triggering mechanisms in this poorly understood phenomenon.

417.05D – Probing Young Star Physics with Aperiodic Variability

Krzysztof Findeisen[1]
1. Caltech, Pasadena, CA, United States.

Ongoing time domain surveys such as PTF, CRTS, and Pan-STARRS1, as well as upcoming surveys such as LSST, promise to revolutionize optical astronomy by providing a comprehensive picture of the variability properties of everything from local flare stars to distant quasars. Time domain surveys have already proven a boon for studies of young stars, whose variability is frequently aperiodic and may have time scales of days to decades, depending on the physics underlying the variability. I present an overview of the PTF-NAN (North America Nebula) survey, which allows us, for the first time, to simultaneously resolve day-scale variability and to monitor changes in photometric behavior in young stars over several years, without large data gaps and without any assumptions about periodicity. I describe preliminary results of the survey, including a search for episodic stellar behavior, a study of the most robust methods for identifying the characteristic time scale(s) of an aperiodic signal, and a characterization of the full range of amplitudes and time scales represented in optical variability of young stars.

417.06D – OBSERVATIONS OF WARM WATER AND VOLATILES IN YOUNG PROTOPLANETARY DISKS, AND THE CONNECTION TO DISK EVOLUTION AND PLANET FORMATION

Andrea Banzatti[1, 2], Michael Meyer[2], Klaus Pontoppidan[1]
1. Space Telescope Science Institute, Baltimore, MD, United States. 2. ETH Zurich, Zurich, Switzerland.

Recent analyses of mid-infrared spectra have shown that warm molecular gas (mainly water, OH, and simple organic molecules) is commonly detected in the inner regions of T Tauri disks and might be an important tracer for the chemical and physical evolution of the terrestrial planet formation region. Many studies suggest that the composition of gas and dust in circumstellar disks (inherited from the ISM and evolved through the protostellar phase) can be further altered by several processes relevant for planet formation. The outcome of this evolution may have important implications concerning the diversity of planetary systems, the composition of planetary surfaces and atmospheres, and on planet habitability. Molecular abundances in the inner disk are a privileged tracer of both the local irradiation environment and the radial transport of icy bodies that evaporate after crossing the snowline, the building blocks of rocky planets. Water and other molecules in the gas phase are therefore strongly connected to our understanding of disk evolution and planet formation processes. In this presentation I will show the highlights from the research I have done during my PhD, using mid-infrared spectroscopy from Spitzer and VLT-VISIR to address: 1) the effect of variable UV radiation in shaping the properties of the molecular gas in inner disks, during accretion phenomena in the T Tauri phase, and 2) the abundance of water vapor inward of the snowline as indicative of its origin through chemical (gas-phase reactions) and/or physical processes (ongoing inward migration of icy solids), and a potential tracer of disk evolution and planet formation processes.

418 – An Astronomical Time Machine: Light Echoes from Historic Supernovae and Stellar Eruptions
Plenary Session – Potomac Ballroom A – 09 Jan 2014 11:40 am to 12:30 pm

418.01 – An Astronomical Time Machine: Light Echoes from Historic Supernovae and Stellar Eruptions

Armin Rest[1]

1. Space Telescope Science Institute, Timonium, MD, United States.

Tycho Brahe's observations of a supernova in 1572 challenged the dogma that the celestial realm was unchanging. Now, 440 years later we have once again seen the light that Tycho saw as simple reflections from walls of Galactic dust. These light echoes, as well as ones detected from other historical events such as Cas A and Eta Carinae's Great Eruption, give us a rare opportunity in astronomy: the direct observation of the cause (the explosion/eruption) and the effect (the remnant) of the same astronomical event. But we can do more: the light echoes let us look at the explosion from different angles, and permit us to map the asymmetries in the explosion. I will discuss how the unprecedented three-dimensional view of these exciting events allows us to unravel some of their secrets.

419 – Giant Magellan Telescope Organization Town Hall

Town Hall – National Harbor 3 – 09 Jan 2014 12:45 pm to 01:45 pm

The GMT Project will hold a town hall to inform the AAS community regarding the status of the project and opportunities for participation in large-scale science projects. We will make short presentations on the status of the project and two science areas. These presentations will be followed by an open discussion of opportunities for community involvement. Members of the GMT Board and project team will be on hand as will members of the instrument science teams.

420 – Transforming NOAO, A Town Hall Discussion

Town Hall – Maryland Ballroom C – 09 Jan 2014 12:45 pm to 01:45 pm

The NSF Astronomy Division has begun to clarify the mission and scope of NOAO in the post Portfolio Review era. Please come and hear about the emerging plans to transform NOAO in the coming years. We invite the community to provide input and commentary as NOAO embarks on a process of change toward large data science in the era of DES, DESI, and LSST.

421 – AGN at Radio to IR Wavelengths
Oral Session – National Harbor 11 – 09 Jan 2014 02:00 pm to 03:30 pm

421.01 – Widefield Surveys of the Low-Frequency Radio Sky with the Murchison Widefield Array

John Morgan[1], Natasha Hurley-Walker[1], Randall Wayth[1]
1. Curtin University, Perth, WA, Australia.
Contributing teams: MWA

The Murchison Widefield Array (MWA) is a low-frequency radio interferometer operating between 80 and 300MHz, located in the mid-west of Australia. It is the low-frequency precursor to the Square Kilometer Array (SKA). The MWA is designed as a widefield survey instrument with a field of view approaching 30° at 150 MHz. This optimizes it for the key science goals of Epoch of Reionisation studies, radio transient searches and Galactic and extra-galactic survey science. Even in early commissioning of the instrument, with just four nights of observing, we were able to survey approximately 9 hr in RA over a declination range of 45°. The data were reduced independently at three different frequencies (119, 150 and 180 MHz). Of order 10,000 sources were detected at 5-? above the confusion noise limit. For each a flux and spectral index was determined. In this talk I will present the results of this commissioning survey, and the early science questions that we hope to answer with this exceptionally rich dataset. I will also introduce the GLEAM survey, which is currently being observed using the fully-commissioned MWA.

421.02 – Millimeter Properties of Radio Sources and the Sunyaev-Zel'dovich Effect

Megan B. Gralla[1], Devin Crichton[1], Tobias Marriage[1]
1. Johns Hopkins University, Baltimore, MD, United States.
Contributing teams: ACT Collaboration, HerMES Collaboration

The Atacama Cosmology Telescope (ACT) is a six-meter telescope in the Atacama Desert that observes simultaneously in frequency bands centered at 148, 218 and 277 GHz. We have used the ACT survey data to statistically study the millimeter properties of radio sources selected from low frequency (1.4 GHz) surveys. We have modeled the average spectral energy distribution of these sources, including a contribution from dust which is constrained by data from Herschel. The Sunyaev-Zel'dovich (SZ) effect associated with the halos that host the radio AGN is detected through its spectral signature in the ACT bands, providing evidence that radio AGN reside in halos that support gaseous atmospheres.

421.03 – Search for unassociated Fermi sources

Leonid Petrov[1], Frank Schinzel[2], Phillip Edwards[4], Elizabeth Mahony[3], Elaine . Sadler[5], David McConnell[4], Gregory B. Taylor[2]
1. Astrogeo Center, Falls Church, VA, United States. 2. University of New Mexico, Albuquerque, NM, United States. 3. ASTRON, the Netherlands Institute for Radio Astronomy, Dwingeloo, Netherlands. 4. CSIRO Astronomy and Space Science, Epping, NSW, Australia. 5. The University of Sydney, Sydney, NSW, Australia.

The Fermi Large Area Telescope catalogue 2FGL lists 1872 objects. More than half of them are Active Galatic Nuclei (AGNs) with strong parsec-scale radio emission detectable with VLBI. But 30% of Fermi sources do not have associations and their nature is a mystery. For solving this mystery we launched a project of observing the fields around unassociated sources first with the Australia Telescope Compact Array (ATCA) and the Jansky Very Large Array (VLA) and then following up detected objects with VLBI. This approach allows us to find those gamma-ray sources that are associated with AGNs brighter than 10-20 mJy. Analysis of the completeness of all-sky VLBI surveys shows that the number of bright radio sources with emission from parsec scales is small enough to make the probability of detection of an unrelated object within the Fermi localisation error ellipse negligible. We discuss the status of the program and preliminary results. Early results suggest there exists a population of radio quiet gamma-ray sources not associated with AGNs that show a greater concentration towards the galactic plane.

421.04 – RadioAstron Measurement of High Brightness Temperature of 3C 273

Kenneth I. Kellermann[1]
1. NRAO, Charlottesville, VA, United States.
Contributing teams: RadioAstron AGN Early Science Team

We report on observations of the quasar 3C 273 with the RadioAstron space to ground interferometer on projected baselines up to 173,000 km. The interferometer data at 1.3 cm between the RadioAstron Spacecraft and both the GBT and the VLA, obtained on a baseline of 7.9 x 10^9 λ, which achieved the highest angular resolution ever reported from any astronomical

measurement, showed structure in the base of the radio jet smaller than about 30 micro arcsec. The observations at 18 cm between the spacecraft and both GBT and Arecibo on projected baselines of up to 9.6×10^8 λ give a direct measure of the brightness temperature of more than about 10^{14} K. This high value is greatly in excess of the 10^{12} K limit expected from inverse Compton cooling or the 10^{11} K expected if there is equilibrium between particle and magnetic energy. Such high observed brightness temperatures are difficult to understand in terms of Doppler boosting since 15 GHz VLBA monitoring of 3C 273 over the past 15 years indicate Lorentz factors of only about 10 to 15. We discuss possible explanations in terms of a continual acceleration of relativistic particles, incoherent radiation from relativistic protons, coherent radiation such as from a synchrotron maser, or a relativistic flow velocity, causing Doppler boosting, that is far in excess of the pattern velocity observed with the VLBA.

421.05 – Detection of a High Brightness Temperature Radio Core in the AGN-Driven Molecular Outflow Candidate NGC 1266

Kristina Nyland[1], Katherine A. Alatalo[2, 3], Lisa Young[1], J. M. Wrobel[4], Raffaella Morganti[5, 6], Timothy Davis[7], P. T. de Zeeuw[7, 8], Susana E. Deustua[9], Martin Bureau[10]
1. New Mexico Tech, Socorro, NM, United States. 2. Infrared Processing and Analysis Center, Caltech, Pasadena, CA, United States. 3. University of California, Berkeley, CA, United States. 4. National Radio Astronomy Observatory, Socorro, NM, United States. 5. Netherlands Institute for Radio Astronomy, Dwingeloo, Netherlands. 6. Kapteyn Astronomical Institute, Groningen, Netherlands. 7. European Southern Observatory, Garching, Germany. 8. Sterrewacht Leiden, Leiden, Netherlands. 9. Space Telescope Science Institute, Baltimore, MD, United States. 10. University of Oxford, Oxford, United Kingdom.

We present new high spatial resolution Very Long Baseline Array (VLBA) continuum observations of the Active Galactic Nucleus (AGN)-driven molecular outflow candidate NGC 1266. Although other well-known systems with molecular outflows may be driven by star formation in a central molecular disk, the molecular mass outflow rate reported in Alatalo et al. (2011) in NGC 1266 of 13 Msun/year exceeds star formation rate estimates from a variety of tracers. This suggests that an additional energy source, such as an AGN, may play a significant role in powering the outflow. Our VLBA observations at 1.65 GHz reveal one continuum source within the densest portion of the molecular gas, with a diameter d < 8 mas (1.2 pc), a radio power of 1.48 x 10^20 W/Hz, and a brightness temperature Tb > 1.5 x 10^7 K that is most consistent with an AGN origin. The radio continuum energetics implied by the compact VLBA source, as well as archival Very Large Array (VLA) continuum observations at lower spatial resolution, further support the possibility that the AGN in NGC 1266 could be driving the molecular outflow. We also present new High Sensitivity Array data, which probes spatial scales intermediate to those observable by existing VLA and VLBA data. In summary, our findings suggest that even low-level AGNs may be able to launch massive outflows in their host galaxies.

421.06 – RoboPol: AGN optical linear polarization monitoring

Oliver G. King[1]
1. California Institute of Technology, Pasadena, CA, United States.
Contributing teams: The RoboPol collaboration

The RoboPol project is using a 4-channel optical polarimeter on the Skinakas 1.3m telescope to monitor the optical linear polarization and R-band magnitude of a large sample of AGN. The RoboPol sample is a gamma-ray selected set of Fermi AGN and is dominated by blazars. The principle goal of RoboPol is to characterize the optical polarization behavior of relativistic jets during high-energy flares, and thereby study the physics of these highly energetic phenomena. The instrument and robotic control system were commissioned in May 2013. We have spent the first year surveying the population of Fermi AGN and monitoring a smaller subset at high cadence. In the second and third years of the project we will monitor a set of ~100 AGN at high cadence. We present the population polarization properties of Fermi AGN and the initial results of our small subset monitoring.

421.07 – Newly Discovered AGN and their Multi-year Light Curves from Kepler

Edward J. Shaya[1], Robert Olling[1], Richard Mushotzky[1]
1. Univ. of Maryland, College Park, MD, United States.

Variability seen at the center of a galaxy is an easy and reliable way to identify AGN. The Kepler space mission provides the ability to find galaxies with very low amplitude variability over a wide range in time delays. We report on a 2 year project to monitor ~400 galaxies with Kepler and our reduction software to stabilize long term photometric trends. We will present light curves for several of our newly discovered AGN with variability measured from the 30 minute to ~2 year timescales. The optical variability that Kepler explores is probably related to accretion disk instabilities, variation in accretion rate or changes in the accretion disk's structure. We developed, in a white paper, a future Kepler project to monitor of order 10,000

galaxies. Statistical analysis of light curves from hundreds of AGN would reveal the physical character of gas, dust or stars falling into AGN or eclipsing the light source and allow better models to be developed of the inner accretion disks/tori. In addition, this project should also find a large number of supernovae and other exotic transient events such as stellar tidal disruption and eta Carinae or P-Cygni type outbursts.

422 – Binary Systems - ULXs and Stellar Collisions
Oral Session – Maryland 2 – 09 Jan 2014 02:00 pm to 03:30 pm

422.01D – Probing the nature of ultraluminous X-ray sources through fast (a few milliseconds) and slow (a few years) X-ray variability

Pasham Dheeraj[1, 2]
1. University of Maryland College Park, College park, MD, United States. 2. NASA/GSFC, Greenbelt, MD, United States.

The X-ray point sources in nearby galaxies with luminosities exceeding the Eddington limiting value of a 20 solar mass black hole (> $3x10^{39}$ ergs/sec) are referred to as ultraluminous X-ray sources (ULXs). Currently, it is unclear whether these sources are powered by super-Eddington accretion onto stellar-mass black holes (mass range of 3-50 solar mass) or if they are intermediate-mass black holes (IMBHs: mass range of a few 100-1000 solar mass) accreting at sub-Eddington rates. In my thesis, I studied the X-ray quasi-periodic variability and long-term modulations of a sample of variable ULXs. My thesis work consists of two parts: (1) understanding the nature of the mHz quasi-periodic oscillations (QPOs) from ULXs (fast variability) and (2) search for and study the properties of the long X-ray periods from ULXs (slow variability). (1) A sample of ULXs exhibit X-ray QPOs in the frequency range of 10-200 mHz. These QPOs have been argued to be analogous to the type-C low-frequency QPOs of stellar-mass black holes (frequency range of 1-15 Hz) but occurring at longer timescales owing to the presence of IMBHs within these systems. We tested this hypothesis by searching for a correlation between the QPO's centroid frequency and the power-law index of the energy spectrum which is a characteristic property of the type-C QPOs of stellar-mass black holes. Using roughly 1 Mega-second of XMM-Newton data from ULXs NGC 5408 X-1 and M82 X-1 we find that the two quantities are NOT correlated. This suggests that one of the strongest arguments for existence of IMBHs in ULXs may be flawed. I will discuss the implications of this result on the masses of the black holes within these systems. (2) Swift/XRT and RXTE/PCA have monitored a sample of ULXs on timescales of 3-6 years. We analyzed all the archival data of these sources to search for periodicities that might represent the orbital motion of the black hole binary. We detected periodicities in some ULXs. I will discuss the various properties of the detected modulations including their coherence, energy dependence, phase-resolved spectroscopy, time-resolved periodograms that will allow us to directly probe the accretion geometries of these systems.

422.02 – An Environmental Study of the Ultraluminous X-ray Source Population in Early-type Galaxies

Richard Plotkin[1], Elena Gallo[1], Brendan P. Miller[2, 1], Vivienne Baldassare[1], Tommaso Treu[3], Jong-Hak Woo[4]
1. Astronomy, University of Michigan, Ann Arbor, MI, United States. 2. Macalester College, Saint Paul, MN, United States. 3. University of California Santa Barbara, Santa Barbara, CA, United States. 4. Seoul National University, Seoul, Korea, Republic of.

Ultraluminous X-ray sources (ULXs) are some of the brightest phenomena found outside of a galaxy's nucleus, and their explanation typically invokes accretion of material onto a black hole. Here, we perform the largest population study to date of ULXs in early-type galaxies. We search for ULXs within the AMUSE survey, which includes homogeneous X-ray coverage of 100 elliptical galaxies in the Virgo cluster and a similar number of elliptical galaxies in the field (spanning stellar masses of 10^8-10^{12} Solar masses), allowing us to perform a focused study on whether a galaxy's large scale environment can affect its ULX content. We find that the number and specific frequency of ULXs, as well as their average X-ray spectral properties, are similar in both cluster and field environments. However, contrary to late-type galaxies, we do not see any trend between specific ULX frequency and host galaxy stellar mass, and we show that dwarf ellipticals host fewer ULXs than later-type dwarf galaxies at a statistically meaningful level. Our results are consistent with ULXs in early-type galaxies probing the luminous tail of the low-mass X-ray binary population, which we will discuss in terms of the properties of a galaxy's (older) stellar population across the galaxy mass scale.

422.03D – Observations and Origins of the Hot DQ White Dwarf Stars

Bart H. Dunlap[1]
1. University of North Carolina at Chapel Hill, Chapel Hill, NC, United States.

Of the two hundred or so white dwarf stars showing spectroscopic signatures of carbon (the DQs), the hottest dozen are unique in having atmospheres actually dominated by carbon and oxygen. Furthermore, many of these hot DQ white dwarfs are photometrically variable, and a large fraction show Zeeman splitting in their spectral lines, revealing the presence of magnetic fields. Based on theoretical pulsational stability studies, pulsations have been proposed to explain the observed brightness variations. However, based on our observations of the hot DQs with the SOAR telescope and using archival data, I will present evidence that the hot DQs are the result of CO-core white dwarf mergers that were not massive enough to explode as Type Ia supernovae. In this scenario, the variable hot DQs are magnetic rotators whose magnetic fields, fast rotation rates, and atmospheric composition are all explained by the merger. As such the masses of the hot DQs will place

lower limits on the mass of the proposed channel of sub-Chandrasekhar double-degenerate Type Ia SNe. And their field strengths and spin periods will provide observational constraints for models of double-degenerate mergers and magnetic field generation.

422.04 – More than scratching the surface: dredge-up in simulations of double white dwarf mergers

Patrick M. Motl[1], Jan E. Staff[2], Cody Raskin[3], Dominic Marcello[4], Geoffrey C. Clayton[4], Chris Fryer[5], Juhan Frank[4]

1. Indiana University Kokomo, Kokomo, IN, United States. 2. Macquarie University, Sydney, NSW, Australia. 3. Lawrence Berkeley National Laboratory, Berkeley, CA, United States. 4. Louisiana State University, Baton Rouge, LA, United States. 5. Los Alamos National Laboratory, Los Alamos, NM, United States.

Previous studies have shown that the strange isotopic abundances of R Corona Borealis stars (e.g. 16O / 18O ~ 1) as well as other properties of these unusual stars may naturally be explained if they originate from the merger of a He white dwarf with a CO white dwarf. However, the merger process that reignites these stellar remnants is highly dynamic and violent. Hydrodynamic instabilities in the accreting star will dredge up oxygen 16 from the accretor at the same time that material from the donor star is fusing to form oxygen 18. Recent stellar evolution calculations have indicated that if dredge up is strongly suppressed, the merger remnant will appear as an R Corona Borealis star but it is not clear how or if dredge up can be shut down. In this presentation we will compare double white dwarf merger simulations performed with three independent codes (SPH, fixed grid Eulerian and adaptive mesh refinement) to ascertain how much accretor material is lifted into the proto-envelope of the merged object.

422.05 – Stellar Collisions within Very Wide Binaries

Nathan A. Kaib[1], Sean N. Raymond[2, 3]

1. Northwestern University, Evanston, IL, United States. 2. Univ. Bordeaux, Foirac, France. 3. CNRS, LAB, Foirac, France.

Although rare in the Milky Way, star-star collisions are predicted to occur within the dense cores of globular clusters, in evolving triple star systems, and possibly very near the Galactic center. It has recently been shown that very wide binary star systems can have their stellar orbits driven to very eccentric states by other passing field stars and the Galactic tide, forcing close passages between companion stars. Here we report numerical simulations demonstrating that this process is a major but unrealized source of stellar collisions. Occasionally, the eccentricities of very wide binaries become so extreme that their periastron falls below the combined radii of the companion stars, and they collide during periastron passage. Tidal interactions between the companion stars prevent some collisions by shrinking the binary orbit thereby making it less susceptible to galactic perturbations. Nonetheless, this mechanism produces a stellar collision every 2500 years in the Galaxy, potentially making very wide binaries the dominant source of collisions in the Milky Way. These collisions should yield a small population of single, Li-depleted, rapidly rotating massive stars.

423 – Black Holes II

Oral Session – National Harbor 10 – 09 Jan 2014 02:00 pm to 03:30 pm

423.01 – Chandra and XMM-Newton identify ~50 black hole binary candidates in M31

Robin Barnard[1], Frank Primini[1], Stephen S. Murray[2, 1], Michael R. Garcia[1]
1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 2. Johns Hopkins University, Baltimore, MD, United States.

We have identified ~50 X-ray binaries (XBs) containing black hole candidates in M31, falling into two groups. The first group exhibited characteristic "hard state" properties at luminosities that exceed the upper threshold for neutron star (NS) XBs; furthermore, their long-term variability, proximity to a globular cluster, or particularly high flux meant that they were highly unlikely to be background galaxies. The second group consists of bright transient X-ray sources that resemble Galactic black hole binaries with low mass donors. A double thermal (disk blackbody + blackbody) emission model has successfully described the full gamut of NS XB spectra, with two exceptions: the hard state, and the horizontal branch of the "Z-source" subclass of NS XBs. Since many of our BHCs are apparently in the hard state, they exist outside the NS parameter space when fitted with the double thermal model. Furthermore, transient BH XBs often exhibit a "thermally dominated" state in outburst that is never observed in NS XBs. For each of our BHCs we estimate the probabiliy that its emission spectrum is consistent with the NS parameter space: BHCs with probability < 0.27% of being consistent with a NS spectrum (equivalent to 3? difference) are rated as Strong BHCs, and the others are "plausible" BHCs.

423.02 – Modeling Hot Gas Flow in the Low-Luminosity Active Galactic Nucleus of NGC3115

Roman V. Shcherbakov[1, 2], Ka-Wah Wong[3], Jimmy Irwin[3], Christopher S. Reynolds[1, 2]
1. University of Maryland, College Park, MD, United States. 2. Joint Space Science Institute, College Park, MD, United States. 3. University of Alabama, Tuscaloosa, AL, United States.

Based on the dynamical estimates of the black hole (BH) mass, NGC3115 hosts the closest billion solar mass BH. Deep studies of the center revealed a very underluminous active galactic nucleus (AGN) immersed in an old massive nuclear star cluster. Recent 1Ms Chandra X-ray visionary project observations of the NGC3115 nucleus resolved hot tenuous gas, which fuels the AGN. In this work we connect the processes in the nuclear star cluster with the feeding of the supermassive BH. We model the hot gas flow sustained by the injection of matter and energy by the stars and supernova explosions. We incorporate electron heat conduction, the gravitational pull of the stellar mass, cooling, and Coulomb collisions. We reach reduced $\chi^2=1$ fitting simulated X-ray emission to the spatially and spectrally resolved observed X-ray data. Radial modeling favors a low BH mass $<1.3*10^{9}$Msun. The best-fitting supernova rate and the best-fitting mass injection rate are consistent with their expected values. The stagnation point is at r_{st}~1arcsec, so that most of gas, including the gas at a Bondi radius r_B=2-4arcsec, outflows from the region. We put an upper limit on the accretion rate at $2*10^{-3}$Msun/yr. We find a shallow density profile n~$r^{-\beta}$ with β~1 over a large dynamic range. This density profile is determined in the feeding region 0.5-10arcsec as an interplay of four processes and effects: (1) the radius-dependent mass injection, (2) the effect of the galactic gravitational potential, (3) the accretion flow onset at r<1arcsec, and (4) the outflow at r>1arcsec. Conduction makes the density profile shallow only very close to the BH at r<0.1arcsec. The gas temperature is close to the virial temperature T_v at any radius. The temperature profile is shallow outside of the Bondi radius because the enclosed stellar mass is proportional to radius M_{enc}~r, which leads to flat virial temperature profile.

423.03 – Modeling Single and Dual Narrow-Line Active Galactic Nuclei

Laura Blecha[1]
1. Univ. of Maryland - College Park, College Park, MD, United States.

It is well-established that merging galaxies have a higher incidence of nuclear activity than their isolated counterparts. Single or dual active galactic nuclei (AGN) observed in ongoing galaxy mergers provide direct evidence of supermassive black hole (SMBH) -- galaxy co-evolution and place indirect constraints on the rate of SMBH mergers. Recent progress in spectroscopic searches for dual AGN has created, for the first time, a statistical sample of candidates. We describe efforts to characterize the signatures of AGN in mergers, focusing especially on their narrow-line profiles. Our previous work indicates that double-peaked narrow-lines, which are used as a selection criterion for dual AGN candidates, can arise from a variety of gas kinematic effects, as well as from dual SMBH motion during mergers. By combining hydrodynamic simulations with dust radiative transfer calculations, including our model for the narrow-line region, we are able to characterize the spectral signatures of single and dual AGN during galaxy mergers. In particular, we describe the substantial effects of dust scattering and obscuration in gas-rich mergers, as well as the contribution of stellar photoionization in the nuclear region to the narrow-line profiles. We discuss the implications of this modeling for future follow-up studies of candidate dual AGN.

423.04D – Outflows from Accreting Black Holes Across the Mass Scale.

Ashley L. King[1]
1. University of Michigan, Ann Arbor, MI, United States.

Winds and jets from accreting black holes can deposit immense quantities of material and energy into their surroundings, affecting black hole growth and even galactic evolution. My thesis work has been to characterize radiative and mechanical feedback from individual black holes using radio jets and X-ray winds. Furthermore, I have shown that ensemble treatments of black holes across the mass scale can potentially determine the underlying physics that drives these outflows. Using these techniques, I have found evidence of high ionization winds that are likely magnetically-driven and arise from the inner accretion disk. Through monitoring efforts, I have also discovered a distinct disk-jet connection in two active galactic nuclei. Finally, I have found evidence that winds and jets scale with accretion luminosity, i.e., accretion rate, in the same fashion across the mass scale. A common relation between winds and jets could indicate a shared launching mechanism.

423.05 – Local Supermassive Black Hole Scaling Relations Imply Compton Thick or Super Eddington Accretion

Gregory Novak[1]
1. Paris Observatory, Paris, France.

A recent analysis of black hole scaling relations, used to estimate the local mass density in black holes, has indicated that the normalization of the scaling relations should be increased by approximately a factor of five (Kormendy and Ho 2013). The local black hole mass density is connected to the mean radiative efficiency of accretion through the time integral of the quasar volume density. The correspondence between this estimate of the radiative efficiency and that expected theoretically from thin-disk accretion has long been used as an argument that most of the growth in black holes occurs via luminous accretion. The increase of the mass density in black holes pushes the mean observed radiative efficiency to values below that expected for thin-disk accretion for any value of the black hole spin, including retrograde accretion disks. This can be accommodated via black hole growth channels that are intrinsically radiatively inefficient, such as super-Eddington accretion, or via growth channels that are intrinsically radiatively efficient but for which few of the photons are observed, such as Compton thick accretion. Measurements of the 30 keV peak in the X-ray background indicate a significant population of Compton thick sources which can explain some, but not all, of the change in the local black hole mass density.

423.06 – X-ray Constraints on the Local Supermassive Black Hole Occupation Fraction

Brendan P. Miller[2, 1], Elena Gallo[1], Jenny E. Greene[3], Brandon C. Kelly[4], Tommaso Treu[4], Jong-Hak Woo[5], Vivienne Baldassare[1]
1. University of Michigan, Ann Arbor, MI, United States. 2. Macalester College, Saint Paul, MN, United States. 3. Princeton University, Princeton, NJ, United States. 4. UCSB, Santa Barbara, CA, United States. 5. Seoul National University, Seoul, Korea, Republic of.

Distinct seed formation mechanisms are imprinted upon the fraction of dwarf galaxies currently containing a central supermassive black hole. Seeding by Pop III remnants is expected to produce a higher occupation fraction than is generated with direct gas collapse precursors. Chandra observations of nearby early-type galaxies can directly detect even low-level supermassive black hole activity, and the active fraction immediately provides a firm lower limit to the occupation fraction. Here, we use the volume-limited AMUSE surveys of ~200 optically-selected early-type galaxies to characterize simultaneously, for the first time, the occupation fraction and the scaling of Lx with Mstar, accounting for intrinsic scatter, measurement uncertainties, and X-ray limits. For early-type galaxies with log (Mstar/Msun) < 10, we obtain a lower limit to the occupation fraction of >20% (at 95% confidence), but full occupation cannot be excluded. The preferred dependence of log Lx upon log Mstar has a slope of around 0.7-0.8, consistent with the "downsizing" trend previously identified from the AMUSE dataset, and a uniform Eddington efficiency is disfavored at ~2 sigma. We provide guidelines for the future precision with which these parameters may be refined with larger or more sensitive samples.

423.07 – The formation of rare massive black holes at redshift 30

Takamitsu Tanaka[1], Miao Li[2]
1. Max Planck Institute for Astrophysics, Garching, Germany. 2. Columbia University, New York, NY, United States.

How supermassive black holes with billions of solar masses formed before redshift 7, when the Universe was less than 800 million years old, remains a theoretical puzzle. One hypothesis is that they grew from ~10^5 Msol black holes formed in the direct collapse of pristine, atomic-cooling (>8000 K) gas. A major uncertainty for this scenario is how the gas can be kept metal free, as dark matter haloes begin forming stars at a virial temperature of ~1000 K. We propose that baryonic streaming, the relative motion of baryons against dark matter at cosmological recombination, is a natural mechanism for delaying star formation and keeping the gas pristine until the halo potential can support conditions for direct collapse. In

rare regions where the local streaming velocities are more than twice the rms value, direct-collapse black holes can form as early as z~30. This scenario can explain the most massive and earliest known quasar black holes, even if only 1% of pristine atomic-cooling haloes form direct-collapse massive black holes.

424 – Circumstellar Disk Topics with some Evolved Star Talks to Boot

Oral Session – Maryland Ballroom B – 09 Jan 2014 02:00 pm to 03:30 pm

424.01 – Evolution of Stellar Coronae: From the Sun to a Red Giant

Vladimir Airapetian[1, 2], James E. Leake[2], Kenneth G. Carpenter[3]
1. Sigma Space/NASA/GSFC, Greenbelt, MD, United States. 2. George Mason University, Fairfax, VA, United States. 3. NASA/GSFC, Greeenbelt, MD, United States.

All stars in the H-R diagram later than spectral class F5 possess a convective zone that provides a reservoir of mechanical energy to drive activity in layers above the photosphere and to shape its atmospheric structures. Cool stars on the main sequence are characterized by compact chromospheres/transition regions and extended coronae transitioning into stellar winds. As the star exhausts its hydrogen fuel and enters into a giant/supergiant phase of its life, its atmospheric structures change dramatically showing signatures of bloated chromospheres and compact coronae. What physical mechanisms are responsible for such a drastic transition from a "dwarf" chromosphere of a cool dwarf star into a "giant" chromosphere of an evolved giant? How does a "giant" corona of a dwarf star evolve into a "dwarf" corona" of a giant star? In this talk we present a unified picture of the evolution of stellar atmospheric structures as a cool stars moves from the main-sequence to a red giant phase. The results of our 2.5D magnetohydrodynamic (MHD) simulations suggest the dynamics of the emergence of magnetic flux into the atmospheres of cool stars is strongly dependent on surface gravity and the magnetic field. We simulate the dynamics of emergence of magnetic field in the Sun, a sug-giant and a giant star. Our simulations suggest that as the surface gravity becomes smaller and the magnetic field weaker as the star evolves, the magnetic flux cannot be transported high enough into the atmosphere to form an extended corona. Instead, it forms highly compact loops in the lower layers of bloated stellar chromospheres and heated by Alfven waves to coronal temperatures.

424.02D – Toward Unraveling the Nature of the Mysterious 21 and 30 Micrometer Emission Features of Evolved Stars

Ajay Mishra[1, 2], Aigen Li[1, 2]
1. University of Missouri, Columbia, MO, United States. 2. University of Missouri, Columbia, MO, United States.

The mysterious "21 micrometer" emission feature seen almost exclusively in the short-lived protoplanetary nebula (PPN) phase of stellar evolution remains unidentified since its discovery two decades ago. This feature is always accompanied by the equally mysterious, unidentified "30 micrometer" feature and the so-called "unidentified infrared" (UIR) features generally attributed to polycyclic aromatic hydrocarbon (PAH) molecules. The 30 micrometer feature is commonly observed in all stages of stellar evolution from the asymptotic giant branch (AGB) through PPN to the planetary nebula phase. We explore the interrelations among the mysterious 21 micrometer, 30 micrometer, and UIR features in the Galactic and Magellanic Cloud 21 micrometer sources. We derive the fluxes emitted in the observed UIR, 21 micrometer, and 30 micrometer features from published ISO or Spitzer/IRS spectra. To derive the stellar mass loss rates of these 21 micrometer sources, we use the 2-dust radiative transfer code for axisymmetric dusty systems to model their dust infrared emission. We found that --- (1) The 30 micrometer feature does not seem to positively correlate with the 21 micrometer feature. This argues against the hypothesis of thiourea and aliphatic chains (attached to various carbonaceous structures) as the common carriers for both the 21 and 30 micrometer features; (2) The 21 micrometer feature does not correlate with the UIR features. This argues against large PAH clusters as a possible carrier for the 21 micrometer feature. (3) The 30 micrometer feature and the UIR features appear to weakly correlate, suggesting that the UIR carriers (e.g. PAHs) may result from the decomposition or shattering of the 30 micrometer feature carrier; and (4) The 21 micrometer feature and UIR features seem to weakly correlate with the stellar mass loss rates while the 30 micrometer feature appears to weakly anti-correlate with the stellar mass loss rates, suggesting that the UIR and 21 micrometer feature carriers are probably synthesized in the PPN phase while the 30 micrometer feature carrier is being destroyed in the PPN phase through decomposition or shattering.

424.03 – Formation of Jets and Vortices on Brown Dwarfs

Xi Zhang[1], Adam P. Showman[1]
1. University of Arizona, Tucson, AZ, United States.

Under the conditions of fast rotation, strong radiative dissipation and no external stellar flux, brown dwarfs occupy a unique corner of the parameter space of atmospheric dynamics theories. In this study, we address a basic question: do the atmospheres of the brown dwarfs exhibit east-west jets pattern as exist on both the gas giants in our solar system and the close-in extra-solar giant planets, or are they dominated by isotropic turbulence and vortices instead? The answer is crucial for the interpretation of observed time variability of L/T dwarfs as well as being of fundamental theoretical interest. We used a global shallow water model to investigate the dominant atmospheric features during the continuous transition from gas giants to brown dwarfs. We simulated the flow motion in the outer atmospheric layer (pressure ~bars) driven by random mass pulses injected from below, representing the convective motions associated with latent heat release in the presence of cloud condensation processes. We show that the existence and properties of the jets crucially depend on several key

parameters including the energy injection rate, the rotation rate, and radiative damping timescale. Under conditions of strong internal heat flux and weak radiative dissipation, east-west jets spontaneously emerge from the interaction of atmospheric turbulence with the planetary rotation. On the other hand, when the internal heat flux is weak and/or radiative dissipation is strong, turbulence injected into the atmosphere damps before it can self-organize into jets, leading to a flow dominated by isotropic turbulence and vortices instead. We also show that faster rotation tends to shrink the deformation radius of the atmosphere so as to suppress the formation of jets. We present a scaling law as a quantitative criterion for the emergence of jets versus vortices on gas giants and brown dwarfs. This work is supported by the NSF and by a Bisgrove Fellowship at the University of Arizona.

424.04 – Searching for spectroscopic binaries within transition disk objects

Saul Kohn[1], Evgenya Shkolnik[2], Alycia J. Weinberger[3], Joleen K. Carlberg[3]
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We have searched for spectroscopic binaries (SB) among 30 pre-main sequence stars that are reported to host transition disks (TD). Twenty-three of these objects are in the star-forming region rho-Ophiuchus and seven are among Coronet, Corona Australis and Chameleon I. We set out to determine whether these disks are truly disks in transition due to some mechanism such as planet formation, or are circumbinary disks. Radial velocities were measured for all targets from high-resolution optical spectra obtained over a two year baseline with the MIKE spectrograph on the 6.5-m Clay Telescope. Only one double-lined SB was found in Ophiuchus. We were sensitive to companions between 0.5 and 25 AU from the primary, complementing earlier high-resolution imaging surveys for stellar companions. We find a deficiency in the binary fraction of Ophiuchus TD stars compared to other SB surveys of that region (4% versus 12-70% quoted in the literature), and we explore possible causes related to disk dispersal mechanisms. Many thanks to the National Science Foundation for their support through the Research Experience for Undergraduates Grant AST-1004107.

424.05D – Peering into Terrestrial Planet Formation: New Studies of Young Debris Disks

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Contributing teams: Herschel GASPS Team

Young debris disks are an excellent tool for studying last stages of terrestrial planet formation. During this stage, planetesimals in the disk might deliver volatiles such as water to the still-forming terrestrial planets. Though these planetesimals are undetectable, the dust in the disk provides clues to the location and composition of their parent bodies. I will discuss my work studying dust in young debris disks (10-30 Myrs-old) in the infrared and sub-millimeter with the Herschel Space Observatory as part of the Herschel GASPS team. We found that there is a lot of scatter in disk properties between disks of the same age, but there appears to be a trend between the stellar and disk temperatures. I will also discuss our detailed modeling of one well-studied debris disk, HD32297. Spectral energy distribution modeling indicates the presence of comet-like grains in the outer disk of HD32297, suggesting the presence of water rich planetesimals that can deliver water to terrestrial planets. HST STIS spectra of this disk show a red color that may be indicative of organic material. Together, these studies help paint a more complete picture of the last stages of terrestrial planet formation in young debris disks.

424.06 – STIS High Contrast Imaging of HD 15745 on Solar System Scales: Inspecting the Fan

John H. Debes[1], Luis Nunez-Quiroga[2], Glenn Schneider[3], Joseph Carson[4], Miwa Goto[5], Carol A. Grady[6], Thomas Henning[5], Dean C. Hines[1], Phil Hinz[3], Hannah Jang-Condell[7], Marc J. Kuchner[8], Amaya Moro-Martin[9], Marshall D. Perrin[1], T. J. Rodigas[11], Gene Serabyn[10], Christopher C. Stark[8], Motohide Tamura[12], Alycia J. Weinberger[11], John P. Wisniewski[13], Bruce E. Woodgate[8]
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We present high contrast visible light imaging of the highly unusual circumstellar debris disk around HD 15745 with the Space Telescope Imaging Spectrograph (STIS) instrument on the Hubble Space Telescope (HST). The combination of two

coronagraphic wedges and three separate spacecraft orientations provides unprecedented signal-to-noise and inner working angle for this disk. We detect the disk to as close as ~0.4" (26 AU) and as far as 6" (380 AU). We confirm the presence of disk emission that extends further to the west as well as evidence for a second, inner disk. Additionally, HD 15745's motion on the sky is parallel to the extended nebulosity observed, raising the possibility that ISM interactions could play a part in its unusual structure. We investigate the plausibility of this scenario. We acknowledge support from STScI for program (GO12228) and its observations.

424.07 – Accretion as a function of Orbital Phase in Young Close Binaries.

David R. Ardila[1], Gregory Herczeg[2], Christopher M. Johns-Krull[4], Robert D. Mathieu[3], Alberto Vodniza[5], Benjamin M. Tofflemire[3]

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Many planets are known to reside around binaries and the study of young binary systems is crucial to understand their formation. Young (<10 Myrs) low-mass binaries are generally surrounded by circumbinary disk with an inner gap. Gas from the disk must cross this gap for accretion to take place and here we present observations of this process as a function of orbital phase. We have obtained time-resolved FUV and NUV spectroscopy (1350 to 3000 A) of DQ Tau and UZ Tau E, using the Cosmic Origins Spectrograph on-board the Hubble Space Telescope. Each target was observed 2 to 4 times per binary orbit, over three or four consecutive orbits. For DQ Tau, we find some evidence that accretion occurs equally into both binary members, while for UZ Tau E this is not the case. H2 emission for DQ Tau most likely originates within the circumbinary gap, while for UZ Tau E no 1000 K gas is detected within the gap, although magnetospheric accretion does take place.

425 – Clouds in Brown Dwarfs and Giant Planets

Special Session – National Harbor 3 – 09 Jan 2014 02:00 pm to 03:30 pm

Clouds play an important role in shaping the emergent spectra of both brown dwarfs and exoplanets. Our poor understanding of the cloud properties (e.g. vertical extent, particle size distribution, and coverage fraction) severely limits our ability to estimate the fundamental physical parameters of brown dwarfs and giant planets. For example, the inferred effective temperatures of the 2M1207b and HR8799 planets differ by up to 600 K depending on the flavor of the cloud models. Atmospheric condensates are also well recognized as a limiting factor in explaining the M/L, L/T, and T/Y spectral type transitions. Periodic variability in cool brown dwarfs, likely caused by uneven cloud coverage, provides a convenient probe of the cloud structure in rotating substellar atmospheres. Mapping the time evolution of cloud-induced variability in brown dwarfs also provides a novel way to study atmospheric circulation in non-irradiated ultracool atmospheres: a regime not accessible from observations of hot Jupiter-type transiting planets. The proposed Special Session shines a timely spotlight on this new approach to exploring ultra-cool atmospheres enabled by recent breakthroughs in precision photometry. On-going ground- and space-based surveys are using this technique to systematically study large samples of brown dwarfs. Several among the invited and confirmed speakers are leading large Spitzer and HST programs to study this phenomenon (3,000+ Spitzer hours and 100+ HST orbits). By the time of the January 2014 AAS meeting, most data will have been obtained and the results can be presented in press releases. The pressing interest in unraveling the cloud structure of directly imaged extrasolar planets and cool brown dwarfs makes the Session broadly relevant to the wider substellar astrophysics community. Through a series of short, exciting talks the community will share in the newest, unpublished results from this rapidly developing field.

425.01 – Clouds and Binaries Across the L/T Transition

Adam J. Burgasser[1]
1. UC San Diego, La Jolla, CA, United States.

The evolution of clouds plays a primary, if not defining, role in shaping the spectral transition from L to T spectral classes, a transition through which all brown dwarfs must pass. The role of clouds is particularly notable in binary systems which straddle this transition. In this talk, I will briefly review the evidence of cloud evolution across the L/T transition and the observable impacts (the 1 μm brightening, binary excess, flattening of luminosities, spectral feature evolution, spectral binaries). I will then go into detail on the most recently discovered L/T transition binary, Luhman 16AB, and present the first results on spectral variability in this system.

425.02 – Brown Dwarf Variability: What's Varying and Why?

Mark S. Marley[1]
1. NASA Ames Research Center, Moffett Field, CA, United States.

Surveys by ground based telescopes, HST, and Spitzer have revealed that brown dwarfs of most spectral classes exhibit variability. The spectral and temporal signatures of the variability are complex and apparently defy simplistic classification which complicates efforts to model the changes. Important questions include understanding if clearings are forming in an otherwise uniform cloud deck or if thermal perturbations, perhaps associated with breaking gravity waves, are responsible. If clouds are responsible how long does it take for the atmospheric thermal profile to relax from a hot cloudy to a cooler cloudless state? If thermal perturbations are responsible then what atmospheric layers are varying? How do the observed variability timescales compare to atmospheric radiative, chemical, and dynamical timescales? I will address such questions by presenting modeling results for time-varying partly cloudy atmospheres and explore the importance of various atmospheric processes over the relevant timescales for brown dwarfs of a range of effective temperatures. Regardless of the origin of the observed variability, the complexity seen in the atmospheres of the field dwarfs hints at the variability that we may encounter in the next few years in directly imaged young Jupiters. Thus understanding the nature of variability in the field dwarfs, including sensitivity to gravity and metallicity, is of particular importance for exoplanet characterization.

425.03 – Brown Dwarf Variability: Past, Present, and Future

Jacqueline Radigan[1]
1. STScI, Baltimore, MD, United States.

The combination of condensate clouds and rapid rotation has long motivated searches for weather phenomena in ultracool (late-M, L and T) dwarf (UCD) atmospheres. Pioneering work in this field dating back as early as 1999 suggested that variability is quite common for UCDs. Yet these early studies were ambiguous: detections were often low amplitude and/or lacking periodicity, and the mechanisms responsible remained unclear. Although there are still more mysteries than answers, observations made in the past 5 years, utilizing continuous monitoring strategies, better instruments, and larger telescopes have demonstrated conclusive and surprisingly large near-infrared variability for a subset of brown dwarfs at the transition between L and T spectral types, suggesting a patchy distribution of silicate clouds in their atmospheres. While the L/T transition is certainly the realm of spectacular variability, recent space-based efforts have confirmed lower levels of variability for a substantial fraction of UCDs at all spectral types. The contribution of magnetism to this variability, especially for early spectral types, is still an open question. For all variable UCDs, multi-wavelength monitoring (from radio to the MIR)

and over a range in timescales (hours to years) will be key to understanding the physical processes governing brightness changes in cool, cloudy atmospheres.

425.04 – Weather on Other Worlds: Results from Variability Monitoring of an Unbiased Sample of L and T Dwarfs with Spitzer

Stanimir A. Metchev[1,2]

1. University of Western Ontario, London, ON, Canada. 2. Stony Brook University, Stony Brook, NY, United States.

Contributing teams: Weather on Other Worlds Spitzer Exploration Science Team

The detection of global weather phenomena in irradiated extrasolar hot Jupiter planets has provided tremendous insights into their atmospheric structure. Non-irradiated substellar atmospheres probe weather in an entirely different regime, where global atmospheric flows result primarily from a combination of rapid rotation and internal convection, e.g., as in the atmosphere of Jupiter, rather than from external forcing. Isolated brown dwarfs are ideal targets for such investigations because they possess planet-like atmospheric dynamics, yet have greater intrinsic brightnesses and lack nearby bright stars to contaminate observations. I will present comprehensive results from the Spitzer Exploration Science program Weather on Other Worlds, which for the first time reveal the cloud properties of the population of isolated substellar objects.

425.05 – Spectral Mapping and Long-Term Monitoring: Details and Dynamics of Condensate Cloud Layers

Daniel Apai[1], Esther Buenzli[4], Davin C. Flateau[1], Stanimir Metchev[3], Jacqueline Radigan[2], Mark S. Marley[7], Adam P. Showman[1], Iain N. Reid[2], Hao Yang[1], Aren Heinze[6], Theodora Karalidi[1], Adam J. Burgasser[10], Patrick Lowrance[8], Etienne Artigau[9], Subhanjoy Mohanty[5]

1. The University of Arizona, Tucson, AZ, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. Western University, London, ON, Canada. 4. Max Planck Institute for Astronomy, Heidelberg, Germany. 5. Imperial College, London, United Kingdom. 6. Stony Brook University, New York, NY, United States. 7. NASA Ames, Mountain View, CA, United States. 8. Spitzer Science Center, Pasadena, CA, United States. 9. University of Montreal, Montreal, QC, Canada. 10. University of California, San Diego, San Diego, CA, United States.

Contributing teams: Spitzer Exploration Science Team: Extrasolar Storms

Rotational phase mapping provides exciting new insights into the physical and chemical properties of condensate clouds in brown dwarfs and - soon - in directly imaged exoplanets. In this talk I will show new results from ongoing Hubble Space Telescope spectral mapping projects, which obtain very high quality spectrally and temporally resolved data of rotating brown dwarfs. In addition, simultaneous HST and Spitzer observations allow us to probe cloud layers at multiple atmospheric depths. In the second part of the talk I will discuss how multi-epoch observations of complete rotations can be used to study the evolution of cloud layers and show first results from the Spitzer Cycle-9 Exploration Science program Extrasolar Storms.

425.06 – Mapping Clouds on Brown Dwarfs

Ian Crossfield[1], Beth Biller[1,2], Josh Schlieder[1], Niall Deacon[1], Mickael Bonnefoy[1], Derek Homeier[3], France Allard[3], Esther Buenzli[1], Thomas Henning[1], Wolfgang Brandner[1], Bertrand Goldman[1], Taisiya Kopytova[1,4]

1. MPIA, Heidelberg, Germany. 2. Institute for Astronomy, Edinburgh, United Kingdom. 3. CRAL-ENS, Lyon, France. 4. IMPRS, Heidelberg, Germany.

Clouds play an important role in shaping the thermal emission of cool substellar objects, including extrasolar planets and brown dwarfs. These bodies presumably host a complex combination of condensation chemistry and strong three-dimensional atmospheric circulation, but characterization of these objects' dynamic atmospheres has so far been largely limited to measurements of globally averaged thermal emission. We present the first two-dimensional map of any brown dwarf obtained using high-resolution VLT/CRIRES Doppler Imaging. Our map allows unambiguous identification of large-scale surface features. Geographic localization of such features provides the best constraints yet on brown dwarf global atmospheric circulation and represents a major step toward understanding the complex processes governing the atmospheres of cool substellar objects.

425.07 – Atmospheric Dynamics of Brown Dwarfs and Directly Imaged Giant Planets

Adam P. Showman[1], Yohai Kaspi[2]
1. Univ. Of Arizona, Tucson, AZ, United States. 2. Weizmann Institute of Science, Rehovot, Israel.

A variety of observations provide evidence for vigorous motion in the atmospheres of brown dwarfs and directly imaged giant planets. Motivated by these observations, we examine the dynamical regime of the circulation in the atmospheres and interiors of these objects. Brown dwarfs rotate rapidly, and for plausible wind speeds, the flow at large scales will be rotationally dominated. We present 3D, global, numerical simulations of convection in the interior, which demonstrate that, at large scales, the convection aligns in the direction parallel to the rotation axis. Convection occurs more efficiently at high latitudes than low latitudes, leading to systematic equator-to-pole temperature differences that may reach ~1 K near the top of the convection zone. The interaction of convection with the overlying, stably stratified atmosphere will generate a wealth of atmospheric waves, and we argue that, as in the stratospheres of planets in the solar system, the interaction of these waves with the mean flow will cause a significant atmospheric circulation at regional to global scales. At large scales, this should consist of stratified turbulence (possibly organizing into coherent structures such as vortices and jets) and an accompanying overturning circulation. We present an approximate analytic theory of this circulation, which predicts characteristic horizontal temperature variations of several to ~50 K, horizontal wind speeds of ~10-300 m/sec, and vertical velocities that advect air over a scale height in ~10^5-10^6 sec. This vertical mixing may help to explain the chemical disequilibrium observed on some brown dwarfs. Moreover, the implied large-scale organization of temperature perturbations and vertical velocities suggests that, near the L/T transition, patchy clouds can form near the photosphere, helping to explain recent observations of brown-dwarf variability in the near-IR.

425.08 – Are Y Dwarfs Partly Cloudy?

Michael Cushing[1]
1. University of Toledo, Toledo, OH, United States.
Contributing teams: Kevin Hardegree-Ullman, Jesica Trucks

Condensate clouds play a critical role in shaping the emergent spectra of both brown dwarfs and gas giant planets. Their impact on the appearance of these objects is perhaps most dramatically illustrated on Jupiter where large holes in the cloud decks allow radiation from deeper, hotter layers of the atmosphere to emerge resulting in the socalled 5 micron "hot spots" seen in thermal images of Jupiter. With the recent discovery of Y dwarfs by NASA's Widefield Infrared Survey Explorer (WISE), we have finally identified a population of ultracool brown dwarfs (Teff < 600 K) whose atmospheric properties are approaching that of Jupiter (Teff=128 K). There are strong theoretical reasons to expect that the condensate clouds in Y dwarfs may also be inhomogeneous so we are monitoring the known sample of Y dwarfs for variability with warm Spitzer at 3.6 and 4.5 microns. I will present preliminary results of our on-going Spitzer program including the first detection of Y dwarf variability at these wavelengths.

425.09 – A Mid-Infrared View of Clouds on Extrasolar Planets

Andy Skemer[1]
1. University of Arizona, Tucson, AZ, United States.

It is generally assumed that the atmospheres of gas giant planets are analogous to the atmospheres of old brown dwarfs because they are (1) approximately the same composition, (2) approximately the same radius (?1 Rjup supported by electron degeneracy pressure) and (3) slowly cooling due to a lack of internal fusion. However, early studies of the handful of directly imaged exoplanets suggest that planets may be cloudier and more turbulent than their older and more massive analogs. A particularly large discrepancy exists in the L-band (3-4 microns), where atmospheric models that have been successfully used to fit brown dwarfs underpredict the 3.3 micron fluxes of the HR 8799 planets by 1-2 magnitudes. To investigate the cloud properties of giant planets, we have obtained photometry in 6 narrow-band 3-4 micron filters for HR 8799, and a broad 3.3 micron filter for 2M1207 b. Our results suggest an evolution in the cloud properties of young low-mass objects.

426 – Cosmology & CMB VI

Oral Session – National Harbor 13 – 09 Jan 2014 02:00 pm to 03:30 pm

426.01D – Intrinsic alignments: cosmology from the large scales & constraining the non-linear regime

Nora Elisa Chisari[1], Cora Dvorkin[2], Rachel Mandelbaum[3], Michael A. Strauss[1], Neta A. Bahcall[1], Eric M. Huff[4]

1. Princeton University, Princeton, NJ, United States. 2. Institute for Advanced Study, Princeton, NJ, United States. 3. Carnegie Mellon University, Pittsburgh, PA, United States. 4. CCAPP, Ohio State University, Columbus, OH, United States.

While intrinsic alignments are usually regarded as a contaminant of cosmic shear measurements, they encode cosmological information and information about the formation history of galaxies. In the first part of the talk, I will discuss the tidal alignment model, which has been shown to reproduce the intrinsic alignments of Luminous Red Galaxies on large scales. I will present prospects of using the intrinsic alignments of Luminous Red Galaxies as a probe of cosmology with ongoing and upcoming surveys. I will focus on baryon acoustic oscillations (BAO) and primordial non-Gaussianity. I will demostrate that the BAO signature can be detected in the correlation function of galaxies and their intrinsic shapes to high significance in upcoming spectroscopic surveys, such as DESI and Euclid. In the second part of the talk, I will focus on the alignment of galaxies in non-linear scales, within clusters of galaxies. I will describe a method to separate the intrinsic alignment of galaxies in the clusters from the lensing signal of galaxies behind the clusters using photometric redshift posterior distributions. Finally, I will present observational constraints on the intrinsic alignment of cluster galaxies in the Sloan Digital Sky Survey "Stripe 82", for clusters between redshifts $0.1<z<0.4$, and discuss implications for upcoming weak gravitational lensing surveys.

426.02 – The Effects of Halo Environment on Halo Occupation Distributions and the Galaxy-Galaxy Correlation Function.

Kushal Mehta[1], Daniel Eisenstein[2], David H. Weinberg[3]

1. University of Arizona, Tucson, AZ, United States. 2. Harvard University, Cambridge, MA, United States. 3. Ohio State University, Columbus, OH, United States.

In the age of precision cosmology, we need to explore the relationship between host halos and galaxy properties with more scrutiny. We measure variations of the halo occupation distribution (HOD) model correlated with the halo environment on ~5 Mpc scales. Using large smoothed particle hydrodynamic simulations we measure the ratio of galaxy stellar mass to halo mass and carefully remove any trends versus halo mass for redshifts $z = 0, 0.35, 0.5, 1.0$. We look at the distribution of central and satellite galaxies individually. We measure that the halo environment does not affect the normalized ratio of central galaxy stellar mass to halo mass to more than 1.3% over 1 decade in halo environment. We do a similar analysis for the number of satellite galaxies in each halo. Despite lower statistics, we do not find any significant trend with respect to halo environment. Finally, we populate the MultiDark N-body simulation with our HOD models to measure the effect of halo environment on the galaxy-galaxy correlation function.

426.04 – Carbon Monoxide Intensity Mapping at Redshift 2-3

Patrick Breysse[1], Ely Kovetz[2], Marc Kamionkowski[1]

1. Johns Hopkins University, Baltimore, MD, United States. 2. University of Texas at Austin, Austin, TX, United States.

The large scale structure of the universe has been well mapped at very high redshift using the CMB and at low redshifts using galaxy surveys, however there is a large range in cosmic history which cannot be probed using either method. A new method called intensity mapping has arisen as a way to study the structure of the universe in between the regimes of galaxy surveys and the CMB. Intensity mapping involves measuring the large scale fluctuations in the intensity of a specific spectral line. By observing at different frequencies, it is possible to observe the matter distribution in different redshift shells. We study the prospects for an intensity mapping survey targeting the CO(1-0) line at a redshift of 2-3. CO lines are primarily emitted from star forming regions, and we find that the power spectrum of CO emission could be used to constrain the physics of star formation at moderate redshifts. We also find that this signal should be detectable with a reasonable signal to noise ratio, and we present survey parameters which should optimize the detectability of the signal.

426.05 – Hydrogen Recombination Lines from the First Luminous Objects

Brian Pomerantz[1], Yuexing Li[1]

1. The Pennsylvania State University, University Park, PA, United States.

Detection of the first-generation galaxies (z ~ 30 ? 10), those responsible for the re-ionization of the Universe, is of great importance to modern cosmology. Information regarding these high-redshift galaxies would allow for a better understanding of cosmological evolution on a smaller scale than ever before possible. One promising form of observation is detection of the hydrogen recombination lines produced in the surronding HII regions. Newly obtained data on the physical conditions of the first Population III stars, galaxies, and QSOs is applied to a previously developed model of hydrogen level populations at high-redshifts, allowing for a realistic calculation of the flux densities of these recombination lines. The effects of maser phenomenon and saturation are also considered. The results of these calculations are presented and the detectability of each source is determined by considering the sensitivity of present and future radio observatories.

426.06 – The Seeds of a Magnetic Universe

Smadar Naoz[1], Ramesh Narayan[1]
1. Harvard University Smithsonian CfA/ITC, Cambridge, MA, United States.

Magnetic fields appear to be present in all galaxies and galaxy clusters, and perhaps even in the smooth low density intergalactic medium. One explanation for these observations is that a seed magnetic field was generated by some unknown mechanism early in the life of the Universe, and was later amplified by various dynamos in nonlinear objects like galaxies and clusters. I will show that a primordial magnetic fields are expected to be generated in the early Universe on purely linear scales through vorticity induced by scale-dependent temperature fluctuations. Residual free electrons left over after recombination tap into this vorticity to generate magnetic field via the Biermann battery process. At redshifts of order a few tens, we estimate a root mean square field strength of order 1e-25–1e-24G on comoving scales ~10kpc. This field, which is generated purely from linear perturbations, is expected to be amplified significantly after reionization, and to be further boosted by dynamo processes during nonlinear structure formation.

426.07 – Transformationally Describing Halo Bias and Exposing Cosmological Information

Mark C. Neyrinck[1], Miguel Angel Aragon-Calvo[1, 2], Donghui Jeong[1], Xin Wang[1]
1. Johns Hopkins Univ., Baltimore, MD, United States. 2. University of California at Riverside, Riverside, CA, United States.

Local density transforms have many uses in large-scale structure. If a logarithm is applied to the matter density field, the statistics are much better-behaved (covariances are reduced), and redshift-space distortions even become easier to model. Also, the biasing of haloes compared to matter is well-described by local transforms, even deeply into voids. For the first time, we cleanly resolve an exponential suppression of halo formation in voids, which is well-fit by the excursion-set model. A void is like a local low-density (open) universe, where fluctuations are suppressed. So forming a galaxy inside a void is as rare as forming a rich cluster in a high-density region. What enables this measurement is the MIP ensemble of N-body simulations, in which halo discreteness, exclusion, and stochasticity are made negligible by stacking hundreds of simulations with the same large-scale cosmic web, but which differ on small scales, i.e. in the way the cosmic web is populated with haloes.

426.08 – The intensity of isotropic diffuse emission measured with the Fermi Large Area Telescope

Keith Bechtol[1]
1. Kavli Institute for Cosmological Physics, Chicago, IL, United States.
Contributing teams: Fermi Large Area Telescope Collaboration

The gamma-ray sky can be decomposed into individually detected sources, diffuse emission attributed to the interactions of cosmic rays with gas and radiation fields in our Galaxy, and a residual all-sky emission component commonly called the isotropic diffuse gamma-ray background (IGRB). The IGRB comprises all extragalactic emissions too faint or too diffuse to be resolved in a given survey, as well as any residual Galactic foregrounds that are approximately isotropic. The first IGRB measurement with the Large Area Telescope (LAT) on board the Fermi Gamma-ray Space Telescope used 10 months of sky-survey data and considered an energy range between 200 MeV and 100 GeV. Improvements in event selection and characterization of particle backgrounds, better understanding of the diffuse Galactic emission, updated emission models for the Earth atmosphere, Sun, and Moon, as well as a longer data accumulation of 50 months, allow for a refinement and extension of the IGRB measurement with the LAT, now covering energies up to several hundred GeV. We discuss the possible presence of a high-energy cutoff (>100 GeV) in the IGRB, as well as systematic uncertainties that impact the shape and normalization of the measured spectrum.

427 – Dark Matter & Dark Energy II

Oral Session – Maryland Ballroom C – 09 Jan 2014 02:00 pm to 03:30 pm

427.01D – Lensing B-mode measurements by the POLARBEAR telescope

Chang Feng[1]
1. University of California, San Diego, La Jolla, CA, United States.
Contributing teams: the POLARBEAR Collaboration

The POLARBEAR experiment measures the temperature and polarization of the Cosmic Microwave Background (CMB). POLARBEAR aims to measure the gravitational lensing of the CMB's polarization both directly in CMB polarization and by cross-correlating POLARBEAR CMB data with Herschel data. We describe the lensing extraction pipeline and its validation using numerous systematics checks.

427.02D – New Microlensing Constraints of Primordial Black Hole Dark Matter based on First Two Years of Kepler Data

Agnieszka Cieplak[1], Kim Griest[2], Matthew Lehner[3, 4]
1. Brookhaven National Laboratory, Upton, NY, United States. 2. University of California San Diego, La Jolla, CA, United States. 3. Academia Sinica, Taipei, Taiwan. 4. University of Pennsylvania, Philadelphia, PA, United States.

Primordial Black Holes (PBHs) remain one of the few Dark Matter (DM) candidates left within the Standard Model of Particle Physics. We have previously found that previous PBH DM limits could theoretically be extended by two orders of magnitude by using the microlensing of the source stars monitored by the Kepler satellite due to its photometric precision and the large projected cross section of the nearby stars. Here we present the experimental results of our study of the first two years of Kepler stellar lightcurves. After eliminating background events such as variable stars, flares, and comets, we have found no microlensing events. We were therefore able to calculate our efficiency of detection by introducing millions of fake microlensing events which included limb-darkening and a corrected finite-source microlensing formalism. By performing this Monte Carlo analysis, we have found that PBHs with masses between 2×10^{-9} $M_{\tiny TM}$ and 10^{-7} $M_{\tiny TM}$ cannot constitute the entirety of the DM, thereby constraining a full order of magnitude of the previously allowed PBH DM mass range.

427.03D – The Intrinsic Alignment of Galaxies and Weak Gravitational Lensing

Jonathan Blazek[1, 2]
1. Ohio State University, Columbus, OH, United States. 2. University of California, Berkeley, Berkeley, CA, United States.

Galaxy intrinsic alignments (IA) are correlations between intrinsic galaxy shapes and the surrounding density field. These correlations can bias weak gravitational lensing measurements and are the most significant source of astrophysical uncertainty for the next generation of lensing experiments. Despite its importance, IA is poorly understood. The work presented here aims to improve our understanding through both modeling and measuring IA. First, we examine the most frequently employed IA model, the tidal (linear) alignment model, in which galaxy shapes are closely correlated with the surrounding gravitational tidal field. The tidal alignment model provides an accurate description of IA on large scales ($r > 10$ Mpc/h), as measured for luminous red galaxies in the Sloan Digital Sky Survey (SDSS). The IA amplitude for these objects, as determined in this analysis, will allow predictions for possible contamination in current and future lensing studies. We explore several ways in which the model could be improved and expanded, including how the relationship between galaxies and their host halos can modulate the strength of IA, as well as relevant effects on smaller scales ($r < 10$ Mpc/h). Second, we develop a method to separate IA from galaxy-galaxy lensing measurements using photometric redshift information. This technique allows the removal of contamination from the desired lensing signal while also providing a probe of IA in different galaxy populations. We employ this method to constrain fractional IA contamination in the SDSS lensing sample to 1-2%, finding that it is a subdominant source of uncertainty at the current level of statistical precision. These developments in both modeling and measurement techniques can be applied in future lensing analyses to mitigate potential contamination from IA. Such considerations will become more important as statistical precision continues to improve.

427.04 – Improved cosmological constraints from a joint analysis of the SNLS and SDSS surveys

Marc Betoule[1], Julien Guy[1], Richard Kessler[3], Jennifer Mosher[2], Pierre Astier[1], Rahul Biswas[3], Patrick El Hage[1], Delphine Hardin[1], John Marriner[4], Reynald Pain[1], Nicolas Regnault[1]
1. LPNHE (CNRS), PARIS, France. 2. University of Pennsylvania, Philadelphia, PA, United States. 3. University of Chicago, Chicago, IL, United States. 4. FNAL, Batavia, IL, United States.

We present recent progress in cosmological constraints from the type Ia supernovae Hubble diagram which results from significant improvements of the SNLS and SDSS surveys photometric calibration accuracy and the use of the full 3 years of the SDSS spectroscopic SN-Ia sample. The high statistics gathered in recent SN-Ia surveys is not fully exploited because of systematic measurement uncertainties. Combining sub-percent accuracy in the relative flux calibration of the two main SNe surveys with detailed Monte-Carlo investigations of light-curve fitter errors, we have decreased systematic errors and provide a mapping of the luminosity distance-redshift relation with a relative precision of about 3% in logarithmic redshift bins ?z/z ~ 0.5 between z=0.02 and $z=0.7. Our joint sample delivers the most sensitive constraints on Dark Energy to date. In combination with the recent CMB measurement from Planck, we obtain an accuracy better than 6% on the equation of state parameter w.

427.05 – Black Hole Universe Model for Explaining GRBs, X-Ray Flares, and Quasars as Emissions of Dynamic Star-like, Massive, and Supermassive Black Holes

Tianxi Zhang[1]

1. Alabama AandM University, Normal, AL, United States.

Slightly modifying the standard big bang theory, the author has recently developed a new cosmological model called black hole universe, which is consistent with Mach's principle, governed by Einstein's general theory of relativity, and able to explain all observations of the universe. Previous studies accounted for the origin, structure, evolution, expansion, cosmic microwave background radiation, and acceleration of the black hole universe, which grew from a star-like black hole with several solar masses through a supermassive black hole with billions of solar masses to the present state with hundred billion-trillions of solar masses by accreting ambient matter and merging with other black holes. This study investigates the emissions of dynamic black holes according to the black hole universe model and provides a self-consistent explanation for the observations of gamma ray bursts (GRBs), X-ray flares, and quasars as emissions of dynamic star-like, massive, and supermassive black holes. It is shown that a black hole, when it accretes its ambient matter or merges with other black holes, becomes dynamic. Since the event horizon of a dynamic black hole is broken, the inside hot (or high-frequency) blackbody radiation leaks out. The leakage of the inside hot blackbody radiation leads to a GRB if it is a star-like black hole, an X-ray flare if it is a massive black hole like the one at the center of the Milky Way, or a quasar if it is a supermassive black hole like an active galactic nucleus (AGN). The energy spectra and amount of emissions produced by the dynamic star-like, massive, and supermassive black holes can be consistent with the measurements of GRBs, X-ray flares, and quasars.

428 – Dwarf & Irregular Galaxies

Oral Session – National Harbor 12 – 09 Jan 2014 02:00 pm to 03:30 pm

428.01 – Finding tiny, gas-rich galaxies in the Local Group

Jennifer Donovan Meyer[1,2], Jana Grcevich[2], Destry R. Saul[2], Joshua G. Peek[2], Mary E. Putman[2]
1. NRAO, Charlottesville, VA, United States. 2. Columbia University, New York, NY, United States.

I will present ongoing work in which we perform ultraviolet (UV) follow-up of a sample of potential dwarf galaxy candidates selected for their neutral hydrogen (HI) properties. As a result of the low UV background seen by the GALEX satellite and its large and publicly available imaging footprint, we are able to identify potential new, low mass galaxies from published GALFA-HI and ALFALFA survey cloud catalogs. We also identify the UV counterparts to a sample of known dwarf galaxies observed by GALFA-HI, yielding a comprehensive picture of the Local Group dwarf galaxy population in the UV. These results indicate that finding dwarf galaxies by first searching for their neutral gas component is a viable method to locate these optically faint systems. We also address the "missing satellite problem" in the context of our results.

428.02D – The H I Chronicles of LITTLE THINGS BCDs

Trisha L. Ashley[1], Caroline E. Simpson[1]
1. Florida International University, Miami, FL, United States.
Contributing teams: LITTLE THINGS

Blue compact dwarf (BCD) galaxies are gas-rich galaxies that have a dense central burst of star formation. A simple explanation for their appearance is an external disturbance, yet many BCDs appear to be isolated and thus are not likely to have been perturbed by an external force. We have studied the H I data of six apparently isolated BCDs in an attempt to understand what triggered the burst of star formation in these BCDs. This research is part of the VLA H I survey, LITTLE THINGS (http://www2.lowell.edu/users/dah/littlethings/) and makes use of the high velocity and angular resolution of LITTLE THINGS data to explore the detailed kinematics and morphology of the H I gas in each galaxy. We have also collected H I data from the GBT to explore the diffuse H I environments of the BCDs. We show that these galaxies have likely been externally perturbed and highlight several of their interesting H I properties.

428.03 – The HI Neighborhoods of Starburst Dwarf Galaxies

Megan C. Johnson[1], Kristen B. McQuinn[1], Baerbel Koribalski[1], Alyson Ford[1], Jeremy Bailin[1]
1. NRAO - Green Bank, Arbovale, NSW, Australia.

We present some recent results from deep HI observations obtained with the GBT and Parkes Radio Telescopes. These data study the tenuous HI environments around a sample of starburst dwarf irregular (dIrr) galaxies with the aim to understand the trigger mechanism responsible for their unsustainable star formation rates. Included in our sample are dIrr galaxies, NGC 1569, NGC 4214, NGC 4163, IC 4662, and ESO154-023. We are looking for HI bridges, streams, rings, filaments and the like as evidence of interactions within their local environments. If detected, these HI signatures can provide a useful method for understanding what the mechanism is for triggering their current starburst activity. Our data probe down to HI sensitivities of ~2 x 10^17 at the 1 sigma level for a 20 km/s line and cover many degrees of sky around each object, which together should unveil any tenuous emission that could be lurking in the outskirts of these systems.

428.04D – Bright and dark: Satellite galaxies as a test of galaxy formation and the nature of dark matter.

Anna Nierenberg[1]
1. UCSB, Santa Barbara, CA, United States.

I present our recent measurements of the spatial distribution and the cumulative luminosity function of satellites up to a thousand times fainter than their hosts, as a function of host stellar mass and morphology between redshifts 0.1 and 0.8, using imaging from the COSMOS fields and a rigorous statistical analysis. I will demonstrate how these measurements provide powerful new constraints for abundance matching and cosmological simulations in the context of both warm and cold dark matter, and how future measurements of faint satellite colors using CANDELS, will provide important distinguishing power between warm and cold dark matter models. In addition, I will present results from a new strong gravitational lens study in which I use spatially resolved spectra obtained with OSIRIS at Keck to place new constraints on the subhalo mass function.

428.05 – Tidal Dwarf Galaxies In Gas-rich Interacting Galaxy Groups

Paul Eigenthaler[1]

1. Pontificia Universidad Católica de Chile, Santiago, Region Metropolitana, Chile.

Galaxy-galaxy interactions in gas-rich galaxy groups or pairs can form tidal bridges and tails. These tidal arms can contain kinematically decoupled structures with active star formation in the same mass range as dwarf galaxies, so-called tidal dwarf galaxies (TDGs). They differ from ordinary dwarf galaxies by their lack of dark matter and higher metallicity content. Compact groups of galaxies are an ideal environment to study the origin and evolution of TDGs since the high spatial volume density of member galaxies allows for frequent and efficient interactions between galaxies forming tidal tails. Hunsberger et al. (1996) identified 47 TDG candidates in Hickson compact groups (HCGs) and estimated that more than 50% of all dwarf galaxies in compact groups are former TDGs. Statistical considerations based on observations of interacting galaxies illustrate that a significant fraction of today's dwarf galaxies could have had a tidal origin. In their early evolution, TDGs can easily be distinguished from classical dwarf galaxies as they are still embedded in large tidal structures and show ongoing star formation, identified via strong Hα emission in these aggregates. Simulations of interacting galaxies, and of TDGs in particular, have shown that TDGs can survive their first starburst event and turn into long-lived dwarf sized objects. Preliminary results from deep Hα imaging with the SOAR telescope to detect new TDGs in a sample of 10 Hickson compact groups will be presented.

428.06 – Kinematically-Decoupled Cores in Dwarf Ellipticals in the Virgo Cluster: Implications for Infallen Groups in Clusters

Elisa Toloba[1,2], Puragra Guhathakurta[1], Glenn van de Ven[3], Alessandro Boselli[4], Thorsten Lisker[5], Reynier Peletier[6]

1. University of California Santa Cruz, Santa Cruz, CA, United States. 2. Carnegie Observatories, Pasadena, CA, United States. 3. Max Planck Institute for Astronomy, Heidelberg, Germany. 4. Laboratoire d'Astrophysique de Marseille-LAM, Marseille, France. 5. Astronomisches Rechen-Institut, Heidelberg, Germany. 6. Kapteyn Astronomical Institute, Groningen, Netherlands.

Contributing teams: SMAKCED collaboration

A small fraction (~8%) of elliptical galaxies contain kinematically-decoupled cores (KDCs), where the kinematical properties of the central region of the galaxy are distinct from those of the main body of the galaxy. KDCs are difficult to detect in dwarf elliptical (dE) galaxies because of their low central surface brightnesses. There was only one statistically robust detection of a KDC in a dE prior to our study. We present spectroscopic evidence for KDCs in two Virgo cluster dEs, VCC 1183 and VCC 1453, that were studied as part of the SMAKCED project. These KDCs have radii of 1.8$''$ (0.14 kpc) and 4.2$''$ (0.33 kpc), respectively. They are distinct from the main body of the galaxy is three ways: (1) inverted sense of rotation; (2) younger and more metal-rich stellar population; and (3) rounder isophotal shape. The frequency of occurence of KDCs and their properties provide important constraints on the formation history of their host galaxies. We discuss different formation scenarios for these KDCs and for dEs in general. The fact that dEs represent the most common galaxy class in clusters and have never been seen in isolation suggests that they are products of environmental processes that transformed their progenitors. However, it is unclear which types of galaxies are dE progenitors and which environmental processes are the most important. These KDCs provide new clues. Dwarf-dwarf wet mergers and gas accretion are argued to be the only mechanisms that can simultaneously explain all of the properties of these KDCs. Both of these mechanisms require that the progenitor had a close companion with a small relative velocity. Thus, we conclude that KDCs in cluster dEs were formed in galaxy pairs residing in poor groups or in isolation whose subsequent infall into the cluster quenched their star formation. This research was supported by a Fulbright fellowship and by a grant from the National Science Foundation.

428.07 – X-ray Binaries and Feedback in Lyman-α Galaxies

Andrea H. Prestwich[1], Floyd Jackson[2], Philip Kaaret[3], Matthew Brorby[3], Timothy P. Roberts[4], Steven H. Saar[1]

1. Harvard-Smithsonian, CfA, Cambridge, MA, United States. 2. University of Toledo, Toledo, OH, United States. 3. University of Iowa, Iowa City, IA, United States. 4. University of Durham, Durham, Durham, United Kingdom.

We describe evidence for a compact, extremely luminous (L_X ? 10^{41} ergs s^{-1}) X-ray source in the Lyman Break Analog (LBA) galaxy Haro 11. The X-ray spectrum is hard with a power-law photon index ??1.2. This source is most likely dominated by an extreme ULX with L_X ? 5×10^{40} ergs s^{-1}, possibly with a contribution of other X-ray binaries and Inverse Compton emission. If this source is a Black Hole Binary (BHB) in the low state, as suggested by the hard X-ray spectrum, the compact object is almost certainly an Intermediate Mass Black Hole (IMBH). Discovery of an IMBH in a low metallicity star bursting dwarf would be significant because (1) such objects may be accreted into larger galaxies to form HLX such as ESO 243-49 HLX-1 and (2) Haro 11 X-1 may be a ``seed'' black hole which is currently growing rapidly to form a supermassive black hole. This source is also coincident with the center of the Lyman-α emission. Outflow from the ULX may occur very early in the life of the starburst and inject enough mechanical power into the Interstellar Medium (ISM) to accelerate it and thus reduce resonant scattering. ULX may be critical to allow Lyman-α photons to escape. Haro 11 and other LBAs are important for understanding the role X-ray binaries play in the evolution of young galaxies.

429 – Emerging Impacts on Structure Formation and AGN Science from NanoHz Gravitational Wave Studies

Special Session – Maryland 1 – 09 Jan 2014 02:00 pm to 03:30 pm

This session will feature presentations and panel-led discussions on astrophysical problems addressed by current and upcoming capabilities of Pulsar Timing Arrays (PTAs). PTAs are uniquely sensitive to the low-frequency (nHz-uHz) gravitational wave spectrum, and are capable of detecting gravitational waves (GWs) from cosmic string loops, inflationary expansion, and binary supermassive black hole binaries formed in galaxy mergers. Excitingly, the sensitivity of pulsar timing has reached the upper range of the GW signal predictions for standard cosmological structure formation scenarios, and electromagnetic observational studies are beginning to discover discrete binary supermassive systems that may offer target systems for PTAs. The presentations in this session will outline: a) the current status of PTAs and realistic near-term sensitivity predictions; b) how the parameters of hierarchical structure formation models affect the expected GW signal; and c) the discovery potential of current electromagnetic surveys for discrete SMBH binary systems. A panel-led discussion will follow on the astrophysical consequences of a GW detection or strict upper limits from a timing array, focusing on unknowns in Universe structure formation, galaxy dynamics, active nucleus formation, and supermassive black hole growth. We also welcome relevant contributed posters, to provide a broader view to the focused discussion in the session. The primary goal of this session is to encourage collaborative thinking between theorists, pulsar timers, and electromagnetic observers on realistic goals in GW astrophysics with supermassive black hole binaries in the coming 1-10 years.

429.01 – A Crash Course in using Pulsars to Detect Gravitational Waves

Andrea N. Lommen[1]
1. Franklin and Marshall College, Lancaster, PA, United States.
Contributing teams: NANOGrav

A collection of well-timed millisecond pulsars makes a "pulsar timing array", an "observatory" capable of detecting and characterizing small perturbations in spacetime called gravitational waves. In this 12-minute crash course you will learn how pulsars are timed, how you can use them to detect gravitational waves, who and what telescopes are engaged in this international enterprise, and how you can get involved.

429.02 – When will NANOGrav detect gravitational waves?

Xavier Siemens[1]
1. University of Wisconsin -- Milwaukee, Milwaukee, WI, United States.

For the better part of the last decade, the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) has been using the Green Bank and Arecibo radio telescopes to monitor millisecond pulsars. NANOGrav aims to directly detect low-frequency gravitational waves which cause small changes to the times of arrival of radio pulses. In this talk I will discuss recent progress made toward realistic simulations of our sensitivity to a stochastic background of gravitational waves, as well as new scaling laws for the significance of a stochastic background detection in pulsar timing data. I will show that a detection is possible as early as 2017. I will also discuss the detection of individual sources of continuous waves, and the prospects for determining some of their parameters.

429.03 – Electromagnetic Signatures of Supermassive Binaries and their Hosts

Jeremy Schnittman[1, 2]
1. NASA/GSFC, Greenbelt, MD, United States. 2. Joint Space Science Institute, College Park, MD, United States.

Supermassive black hole binaries will be the strongest gravitational wave sources in the universe. The systems most likely to be observed with pulsar timing arrays will have particularly high masses ($>\sim 10^9$ M_sun), long periods (T_orb $>\sim 1$ year), and and be in the local universe ($z <\sim 1$). These features are also the most favorable for bright electromagnetic counterparts, which should be easily observable with existing ground- and space-based telescopes. The primary challenge lies in correctly identifying and characterizing binary sources with long orbital periods, as opposed to "normal" active galactic nuclei hosting single black holes. Here we outline theoretical and observational strategies for the unambiguous detection of black hole binaries in the near future.

429.04 – I Get By With A Little Help From My Friends: Enhancing PTA Sensitivity to GWs With EM Counterparts

Justin Ellis[1], Sarah Burke-Spolaor[2]
1. University of Wisconsin Milwaukee, Milwaukee, WI, United States. 2. Caltech, Pasedena, CA, United States.

Gravitational Waves (GWs) are tiny ripples in the fabric of space-time predicted by Einstein's theory of General Relativity.

Pulsar timing arrays (PTAs) offer a unique opportunity to detect low frequency GWs in the near future. Such a detection would be complementary to both LIGO and and future space based GW efforts. In the low (1e-9 - 1e-7 Hz) frequency band, the expected source of GWs is a stochastic background resulting from the ensemble of supermassive black hole binaries (SMBHBs) formed during the merger of galaxies, and possibly a few nearby/massive sources that will be individually resolvable. In this talk we will discuss the interplay between EM and GW observations of SMBMBs and will answer two questions: (i) How will an independent EM observation of an SMBHB increase the GW detection significance with PTAs? and (ii) How will this independent EM observation improve GW parameter estimation with PTAs?

429.05 – Probing Massive Black Hole Binaries with Pulsar Timing Arrays

Alberto Sesana[1]
1. Albert Einstein Institute, Munich, Germany.

Pulsar timing arrays (PTAs) provide a promising tool to probe massive black hole binaries in the low redshift Universe. The strength of the emitted gravitational wave signal depends on several crucial parameters of the binary population, namely their masses and their space density. I will discuss how the signal depend on such parameters and what we can learn about these elusive objects with PTA observations in the near future.

430 – Extrasolar Planet Detection - M Dwarfs and Young Stars

Oral Session – Maryland Ballroom A – 09 Jan 2014 02:00 pm to 03:30 pm

430.01D – Planets, Cycles, and Starspots: Disentangling Stellar Activity from Radial Velocity for Cool Stars

Paul Robertson[1, 2], Michael Endl[3, 2], William D. Cochran[3, 2], Sarah E. Dodson-Robinson[4], Phillip MacQueen[3, 2]

1. Center for Exoplanets and Habitable Worlds, Penn State University, University Park, PA, United States. 2. The University of Texas, Austin, TX, United States. 3. McDonald Observatory, Austin, TX, United States. 4. The University of Delaware, Newark, DE, United States.

Because Kepler has established the preponderance of small, potentially habitable exoplanets, current and upcoming radial velocity (RV) surveys concentrate on finding Earth-mass planets orbiting stars near enough to facilitate detailed follow-up observations. Particularly attractive targets are cool, low mass "M dwarf" stars. Their low masses (and thus higher planetary RV amplitudes) and close-in habitable zones facilitate relatively quick detection of low mass planets in the habitable zone. However, the RV signals of such planets will be obscured by stellar magnetic activity, which is poorly understood for M stars. In an effort to improve the detection capabilities of the Hobby-Eberly Telescope M dwarf planet survey, I have conducted a detailed investigation of the magnetic behavior of our target stars. Here, I present techniques for identifying magnetic activity cycles and rotation periods for old, quiet M stars and evaluating their effects on RV measurements. I will discuss new insights into the magnetic behavior of these stars, and demonstrate some early results of correcting stellar activity in order to reveal exoplanet signals.

430.02 – Precise Near-Infrared Radial Velocities

Peter Plavchan[1, 2], Peter Gao[1], Michael Bottom[1], Cassy Davison[3], Sean Mills[12], David R. Ciardi[1, 2], Carolyn Brinkworth[1], Angelle M. Tanner[10], Charles A. Beichman[1, 2], Joseph Catanzarite[13], Sam Crawford[4], J. Kent Wallace[4], Bertrand Mennesson[4], John A. Johnson[5], Russel J. White[3], Guillem Anglada-Escudé[6], Kaspar von Braun[7], Bernie Walp[11], Gautam Vasisht[4], Stephen R. Kane[9], Lisa A. Prato[8]

1. Caltech, Pasadena, CA, United States. 2. NExScI, Pasadena, CA, United States. 3. Georgia State University, Atlanta, GA, United States. 4. Jet Propulsion Laboratory, Pasadena, CA, United States. 5. Harvard University, Cambridge, MA, United States. 6. University of Goettingen, Goettingen, Germany. 7. Max Planck Institute for Astronomy, Heidelberg, Germany. 8. Lowell Observatory, Flagstaff, AZ, United States. 9. San Francisco State University, San Francisco, CA, United States. 10. Mississippi State University, Mississippi State, MS, United States. 11. SOFIA, Moffett Field, CA, United States. 12. University of Chicago, Chicago, IL, United States. 13. NASA Ames, Moffett Field, CA, United States.

Contributing teams: NIRRVs

We present precise radial velocity time-series from a 2.3 micron pilot survey to detect exoplanets around red, low mass, and young stars. We use the CSHELL spectrograph with an isotopic methane absorption gas cell for common optical path relative wavelength calibration at the NASA InfraRed Telescope Facility. We present an overview of our Nelder-Mead simplex optimization pipeline for extracting radial velocities. We will also present first light data at 1.6 microns from a near-infrared fiber scrambler used in tandem with our gas cell and CSHELL at IRTF. The fiber scrambler makes use of non-circular core fibers to stabilize the illumination of the slit and echelle grating against changes in seeing, focus, guiding and other sources of systematic radial velocity noise, complementing the wavelength calibration of a gas cell.

430.03 – Observations of the Pre-Main Sequence Exoplanet Candidate PTFO 8-8695

David R. Ciardi[1, 2], Charles A. Beichman[1, 2], Sean J. Carey[1, 3], Christopher Crockett[4], Christopher M. Johns-Krull[5], Stephen R. Kane[6], Jacob McLane[7, 4], Peter Plavchan[1, 2], Lisa A. Prato[4], John R. Stauffer[1, 3], Gerard van Belle[4], Julian C. Van Eyken[8, 9], Kaspar von Braun[10]

1. Caltech, Pasadena, CA, United States. 2. NExScI, Pasadena, CA, United States. 3. Spitzer, Pasadena, CA, United States. 4. Lowell Obs., Flagstaff, AZ, United States. 5. Rice University, Houston, TX, United States. 6. SFSU, San Francisco, CA, United States. 7. NAU, Flagstaff, AZ, United States. 8. UCSB, Santa Barbara, CA, United States. 9. LCOGT, Santa Barbara, CA, United

States. 10. MPIA-Heidelberg, Heidelberg, Germany.

PTFO 8-8695 is a weak-lined T-Tauri star in the 7-10 Myr old Orion-OB1a/25-Ori region discovered to have a transiting body in an orbital period of 0.45 days. Initial follow-up radial velocity observations in the optical with Keck and the HET and light curve modeling ruled out stellar binarity and stellar spots as possible causes of the transit events, and yielded an upper limit on the mass of the transiting object of 5 MJupiter. We have conducted further observations with the Spitzer Space Telescope and the Keck Observatory in an effort to confirm the planetary nature of the transiting object and better determine its mass. We present a Spitzer 4.5 um light curve and a Keck NIRSPEC radial velocity curve which confirm the transit and place more stringent limits on the mass limits of the planetary candidate.

430.04 – A Confirmed Directly Imaged Planet Orbiting a Nearby Young, Dusty Star

Thayne M. Currie[1], Julien Rameau[2], Gael Chauvin[2], Anne-Marie Lagrange[2], Anthony Boccaletti[3], Tiffany Meshkat[4], Sascha Quanz[5], Julien Girard[6], Mickael Bonnefoy[7], Matthew A. Kenworthy[4]

1. University of Toronto, Toronto, ON, Canada. 2. IPAG, Grenoble, France. 3. LESIA/Observatoire de Paris, Paris, France. 4. Leiden Observatory, Leiden, Netherlands. 5. ETH-Zurich, Zurich, Switzerland. 6. ESO, Santiago, Chile. 7. MPIA-Heidelberg, Heidelberg, Germany.

We present new VLT/NaCo infrared (Lp/3.8 micron) high-contrast imaging observations of a nearby, young (13--21 Myr old) star known to be surrounded by a luminous Kuiper belt-like debris disk. Using multiple reduction pipelines, we unambiguously detect a faint companion located interior to the disk at a projected separation of ~55 AU in four separate data sets between 2012 and 2013. The companion's astrometry is decisively inconsistent with that of a background object. Combining our Lp photometry with sensitive upper limits at shorter wavelengths shows that the companion has red colors characteristic of young jovian planets with an inferred mass of 3--7 Mj, making it potentially the lowest mass planet imaged thus far. This planet will be a benchmark for further physical and orbital characterization of young gas giants.

431 – Galaxy Clusters in High Energies and Radio

Oral Session – National Harbor 5 – 09 Jan 2014 02:00 pm to 03:30 pm

431.01D – Characterization of ICM Temperature Distributions of 62 Galaxy Clusters with XMM-Newton

Kari A. Frank[1], John R. Peterson[2], Karl Andersson[3], Andy C. Fabian[4], Jeremy S. Sanders[4]
1. Pennsylvania State University, State College, PA, United States. 2. Purdue Univ., West Lafayette, IN, United States. 3. Ludwig-Maximilians-Universität, München, Germany. 4. Institute of Astronomy, Cambridge, United Kingdom.

We measure for the first time the intracluster medium temperature distributions for 62 galaxy clusters in the HIFLUGCS, an X-ray flux-limited sample, with available X-ray data from XMM-Newton. We search for correlations between the width of the temperature distributions and other cluster properties, including median cluster temperature, luminosity, size, presence of a cool core, AGN activity, and dynamical state. We use a Markov Chain Monte Carlo analysis which models the ICM as a collection of X-ray emitting smoothed particles of plasma. Each smoothed particle is given its own set of parameters, including temperature, spatial position, redshift, size, and emission measure. This allows us to measure the width of the temperature distribution, median temperature, and total emission measure of each cluster. Of all 62 clusters, none have a temperature width consistent with isothermality. Counterintuitively, we also find that the temperature distribution widths of disturbed clusters tend to be wider than in relaxed clusters. The presence of cluster to cluster variations in the shape of the temperature distributions and intrinsic scatter in the temperature distribution widths of ~0.55 keV suggest the exact details of each cluster's unique thermal and dynamic history probably have a significant effect on the temperature distribution. This potentially makes the temperature distribution widths a very useful quantity, both for determining the dynamical state of a cluster independently of its cooling status, and for investigating the interplay between ICM cooling and mergers.

431.02 – X-ray and Radio Results for Abell 2443, a Sloshing Galaxy Cluster Hosting an Ultra-Steep Spectrum Radio Source

Tony Mroczkowski[1], Tracy E. Clarke[1], Scott W. Randall[2], Craig L. Sarazin[3], Elizabeth L. Blanton[4], Simona Giacintucci[5], Huib Intema[6], John A. ZuHone[7]
1. Naval Research Laboratory, Washington, D.C, DC, United States. 2. Chandra X-ray Center, Cambridge, MA, United States. 3. University of Virginia, Charlottesville, VA, United States. 4. Boston University, Boston, MA, United States. 5. University of Maryland, College Park, MD, United States. 6. NRAO, Charlottesville, VA, United States. 7. Goddard Space Flight Center, Greenbelt, MD, United States.

Diffuse radio emission permeating the cluster gravitational potential reveals the widespread presence of relativistic particles and magnetic fields in the intracluster medium (ICM). This emission is observed in numerous clusters which are dynamically complex. The radio emission is observationally classified as halo or relic. Additional low frequency ICM emission is detected from cluster-center radio galaxies which are important for energy feedack into the ICM. I will present recent low frequency radio (VLA and GMRT) data and Chandra X-ray results on several cluster systems. The recently discovered ultra-steep spectrum source in Abell 2443 may be a member of the relatively rare class of adiabatically compressed radio relics. Chandra observations reveal the presence of two surface brightness edges in the ICM and new GMRT observations provide additional details of the spectral index distribution in the ICM. Upcoming improvements in radio instruments will be crucial for expanding our understanding of the relativistic particle and magnetic field content of the ICM. I will briefly discuss a new exploratory concept (LOBO or LOw Band Observatory) which could enable low band (<500 MHz) observing using the new NRL/NRAO Low Band receivers in parallel with all high frequency VLA observing programs.

431.03 – Deep Radio Observations of the Toothbrush Galaxy Cluster

Reinout J. Van Weeren[1], Christine Jones[1], William R. Forman[1], Huub Röttgering[2], Marcus Brüggen[3], Gianfranco Brunetti[4], Francesco de Gasperin[3], Annalisa Bonafede[3], Roberto Pizzo[6], Chiara Ferrari[5], Emanuela Orrù[6], Georgiana A. Ogrean[3]
1. Smithsonian Astrophysical Observatory, Cambridge, MA, United States. 2. Leiden University, Leiden, Netherlands. 3. University of Hamburg, Hamburg, Germany. 4. INAF Istituto di Radioastronomia, Bologna, Italy. 5. Observatoire de la Côte d'Azur, Nice, France. 6. ASTRON, Dwingeloo, Netherlands.
Contributing teams: LOFAR Busyweek team, LOFAR surveys KSP

We present LOFAR and JVLA radio observations of the Toothbrush galaxy cluster. The Toothbrush cluster hosts diffuse 2 Mpc extended radio emission in the form of a radio relic and halo. XMM-Newton X-ray observations show that the cluster is

undergoing a major merger event. Both the radio relic and halo are likely related to this ongoing merger. Radio relics are proposed to be direct tracers of shock waves in the intracluster medium. The XMM observations indeed reveal a shock, but there is a puzzling 200 kpc spatial offset between the shock position and relic. Our deep LOFAR and JVLA observations allow a detailed spectral study to test the shock origin of the relic and underlying particle acceleration mechanisms. Finally, the LOFAR observations highlight the science that could be obtained from a deep low-frequency all-sky survey.

431.04 – Search for Cosmic-ray induced ?-ray Emission in Galaxy Clusters

Stephan Zimmer[1, 2], Anders Pinzke[1], Christoph Pfrommer[3]
1. Oskar Klein Center for Cosmoparticle Physics and Department of Physics, Stockholm University, Stockholm, Stockholm, Sweden. 2. for the Fermi-LAT Collaboration, Stanford, CA, United States. 3. Heidelberg Institute for Theoretical Studies, Heidelberg, Germany.
Contributing teams: The Fermi-LAT Collaboration

Current theories predict relativistic hadronic particle populations in clusters of galaxies in addition to the already observed relativistic leptons. In these scenarios hadronic interactions give rise to neutral pions which decay into ? rays, that are potentially observable with the Large Area Telescope (LAT) on board the Fermi space telescope. We present a joint likelihood analysis searching for spatially extended ?-ray emission at the locations of 50 galaxy clusters in 4 years of Fermi-LAT data under the assumption of the universal cosmic-ray model proposed by Pinzke & Pfrommer (2010). We find an excess at a significance of 2.7? which upon closer inspection is however correlated to individual excess emission towards three galaxy clusters: Abell 400, Abell 1367 and Abell 3112. We discuss these cases in detail and conservatively attribute the emission to unmodeled background (for example, radio galaxies within the clusters). Through the combined analysis of 50 clusters we exclude hadronic injection efficiencies in simple hadronic models above 25% and establish limits on the cosmic-ray to thermal pressure ratio within the virial radius, R200, to be below 0.012-0.014 depending on the morphological classification. In addition we derive new limits on the ?-ray flux from individual clusters in our sample.

431.05 – Recent Results on Clusters of Galaxies with LOFAR

Michael W. Wise[1, 2]
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Contributing teams: The LOFAR Surveys KSP Cluster Working Group

We report on preliminary results from a sample of clusters of galaxies observed during LOFAR's first year of full science operations. Operating in the low-frequency radio regime from 10-240 MHz, the International LOFAR Telescope (ILT) provides unprecedented sensitivity and arcsec-resolution imaging capabilities for studying the synchrotron emission from relativistic particles and magnetic fields present in the intra-cluster-medium (ICM). On larger scales, these non-thermal components can play an important role in controlling transport processes in clusters, and are also sources of additional energy and pressure support in the ICM. Understanding the origins and evolution of these non-thermal components is essential for the reliable use of clusters as tools both for cosmology and astrophysics. Similarly, the interaction between strong, central radio sources and the surrounding ICM can have a dramatic impact on the energetics and morphology of the central regions in clusters. Low-frequency radio observations of bubbles and jets of relativistic particles and magnetic fields launched from these central radio sources can provide information on the effects of this feedback on the evolution of the cluster as well as that of the radio source and central supermassive black hole (SMBH) itself. In this contribution, we will present an overview of results for a sample of bright, nearby clusters that have been observed during the commissioning phase and LOFAR's first year of full science operations. We will present images for a number of well-known clusters observed in both LOFAR's low (30-80 MHz) and high (110-180 MHz) frequency bands. These include well-known relic or halo systems (A2256, A2255, A1682, and A1914) as well as systems known for strong signatures of feedback (Cygnus A, Perseus, Hydra A, Hercules A, M87, and MS0735.6+7421). We will also present preliminary results based on the larger sample of clusters identified in LOFAR's first shallow, all-sky survey (Multifrequency Snapshot Sky Survey or MSSS) and a look ahead to the deeper surveys to follow.

431.06 – Understanding the Toothbrush Merging Galaxy Cluster to Constrain Dark Matter

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Merging galaxy clusters have proven to be one of the most important probes of dark matter self-interaction properties. If their full dark matter constraining power is to be realized though, we must accurately quantify the properties of these dissociative mergers. Some properties such as mass and relative line of sight velocity can be directly measured and sufficiently constrained, but there remains considerable uncertainty on indirect properties of the mergers. Indirect properties such as the angle of the merger axis with the plane of the sky and collision velocity are crucial to translating the gravitational lensing measurements of the mass, X-ray measurements of the cluster gas and optical measurements of the galaxies into constraints on the dark matter properties. By utilizing multi-wavelength measurements (X-ray to radio), of the Toothbrush

radio relic dissociative merger (1RXS J0603+4212) we show that we can improve the constraints on the indirect parameters of the merger by up to an order of magnitude vs. traditional approaches. By utilizing multi-wavelength measurements (X-ray to radio), of the Toothbrush radio relic dissociative merger we show that we can improve the constraints on the indirect parameters of the merger by up to an order of magnitude vs. traditional approaches.

432 – Galaxy Evolution at z~1
Oral Session – Potomac Ballroom A – 09 Jan 2014 02:00 pm to 03:30 pm

432.01 – A search for z <1.2 Ly-alpha Blobs using SWIFT

Teresa Ashcraft[1], Paul Hegel[1], Rolf A. Jansen[1], Michael J. Rutkowski[2], Rogier A. Windhorst[1]
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A recent major discovery has been that of "blobs" of Ly-α (LABs) emission at high (z > 1.7) redshift. These objects are distinguished by their relative lack of stellar continuum emission, large physical and angular sizes, and are found in regions of high galaxy density. The limited information available on LABs makes their nature unclear. Possibilities include cooling radiation from collapsing protogalactic clouds, cold gas stream accretion onto dark matter halos, superwinds from massive starbursts, and gas photoionized by obscured or transient AGN. As with any new class of object, more data and larger samples are needed to narrow down the range of possibilities. Below z ~ 1.7, Lyα detection require space-based observations. Keel et al. (2009) used deep GALEX grism observations of two fields centered on galaxy clusters at z = 0.8, in order to constrain the comoving space density of the LAB population at that redshift. No LABs were detected. Based on limited data, this result suggest a rapid decrease in the space density of LABs since z ~ 2. Using Swift's unique ultraviolet imaging capability, we attempt to locate z < 1.2 Ly-α Blobs to refine the lower bound of the LAB space density function. We test the theory that blob activity is regulated in part by cluster formation by searching for blobs in the vicinity of QSOs. Our search consisted of 130 observations with the Swift/UVOT instrument's UVW1 (corresponds to Ly-α at z ~ 1.1) and UVW2 (corresponds to Ly-α at 0.55) filters centered on QSOs at z ~0.55. To probe the hosts of our Ly-α Blob candidates, we obtained follow-up ground-based optical observations of 30 candidates using the VATT 4k CCD in the U, B, and V filters. We present SEDs for the most promising objects and a census of the contents of our UVOT fields.

432.02D – Star Formation Quenching and Identifying AGN in Galaxies

Alexander Mendez[1], Alison L. Coil[1], Jennifer M. Lotz[2], James Aird[6], Aleksandar M. Diamond-Stanic[7], John Moustakas[4], Samir Salim[3], Luc Simard[5], Michael R. Blanton[8], Daniel Eisenstein[10], Kenneth C. Wong[11], Richard J. Cool[9], Guangtun Zhu[12]
1. UCSD, La Jolla, CA, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. Indiana University, Bloomington, IN, United States. 4. Siena College, Siena, NY, United States. 5. University of Victoria, Victoria, BC, Canada. 6. Durham University, Durham, United Kingdom. 7. University of Wisconsin, Madison, WI, United States. 8. New York University, New York, NY, United States. 9. MMT Observatory, Tucson, AZ, United States. 10. Harvard, Cambridge, MA, United States. 11. University of Arizona, Tucson, AZ, United States. 12. Johns Hopkins University, Baltimore, MD, United States.
Contributing teams: PRIMUS, AEGIS

I will discuss two observational projects related to galaxy and active galactic nuclei (AGN) evolution at z < 1. First I will present a statistical study of the morphologies of galaxies in which star formation is being shut down or quenched; this has implications for how red, elliptical galaxies are formed. I will discuss the physical processes behind star formation quenching from the morphological transformations that galaxies undergo during this process. Then I will focus on multi-wavelength AGN selection methods and tie together disparate results in the literature. Several IR-AGN selection methods have been developed using Spitzer/IRAC data in order to supplement traditional X-ray AGN selection; I will characterize the uniqueness and complementarity of these methods as a function of both IR and X-ray depth. I will use data from the PRIsm MUlti-object Survey (PRIMUS) to compare the efficiency of IR and X-ray AGN selection and discuss the properties of the AGN and host galaxy populations of each. Finally, I will briefly mention ongoing work to compare the clustering of observed IR and X-ray AGN samples relative to stellar mass-matched galaxy samples.

432.03 – The Starburst-AGN Connection in Luminous and Ultraluminous Infrared Galaxies

Stephanie Fiorenza[1, 2], Tsutomu T. Takeuchi[3], Katarzyna E. Malek[3], Charles Liu[2]
1. CUNY Graduate Center, New York, NY, United States. 2. CUNY College of Staten Island, Staten Island, NY, United States. 3. Nagoya University, Nagoya, Aichi Prefecture, Japan.

The evolutionary connection between nuclear starbursts and AGN in luminous infrared galaxies (LIRGs; $10^{11} < L_{IR} < 10^{12}$ L™) and ultraluminous infrared galaxies (ULIRGs; $10^{12} < L_{IR} < 10^{13}$ L™), which result from galaxy interactions and mergers and produce the bulk of their radiation as infrared (IR) emission, is not well understood. To this effort, we examine the optical spectra and multiwavelength spectral energy distributions of 6 objects from the IRAS 2 Jy Redshift survey with 0.05 < z <

0.16: Arp 195, IRAS 10311+3507, IRAS 12112+0305, 3C 273, IRAS 13458+1540, and IRAS 17501+6825. We classify the primary source of IR radiation as being a nuclear starburst (HII-region-like galaxy) or a type of AGN (Seyfert galaxy or LINER) by using key emission line ratios. We then use optical, near-, and mid-infrared photometric measurements to perform SED-fitting with CIGALE (Code Investigating GALaxy Emission), which allows us to measure several physical parameters, including the AGN-contribution to the bolometric luminosity (L_{bol}) and the age of the most recent starburst activity. We find that the AGN contributions to L_{bol} range from 1.1-1.5%, with the exception of 3C 273, whose powerful QSO contributes 87% of L_{bol}. Comparing the starburst ages with the IR-power source classifications and with the starburst/AGN contributions provides clues about which type of IR-power source forms first in U/LIRGs, the evolutionary stage at which the transformation of the IR-power source occurs, and how starburst age varies with starburst/AGN strength in U/LIRGs.

432.04 – Massive Star-Forming Host Galaxies of Quasars on SDSS Stripe 82

Yoshiki Matsuoka[1, 2], Michael A. Strauss[1]
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The interrelation between supermassive black holes (SMBHs) and their host galaxies is a central issue of astrophysics today. Here we present our latest results on the stellar properties of about 800 galaxies hosting optically luminous, unobscured quasars at z < 0.6. Deep co-added Sloan Digital Sky Survey (SDSS) images of the quasars on Stripe 82 are decomposed into nucleus and host galaxy using point spread function and Sersic models. Quasar light contamination in measured host brightness, due to imperfect nucleus/host decomposition or scattering by the interstellar medium of host galaxies, is carefully addressed. The resultant quasar-to-galaxy ratio in total flux decreases toward longer wavelengths, from ~8 in the u band to ~1 in the i and z bands. We find that the SDSS quasars are hosted exclusively by massive galaxies (stellar mass Mstar > 10^{10} Msun), which is consistent with previous results for less luminous narrow-line (obscured) AGNs. The quasar hosts are very blue and almost absent on the red sequence, showing stark contrast to the color-magnitude distribution of normal galaxies. The fact that more powerful AGNs reside in galaxies with higher star-formation efficiency may indicate that negative AGN feedback, if it exists, is not concurrent with the most luminous phase of AGNs. We also find positive correlation between the mass of SMBHs (Mbh) and host stellar mass, but the Mbh - Mstar relation is offset toward large Mbh or small Mstar compared to the local relation. While this could indicate that SMBHs grow earlier than do their host galaxies, such an argument is not conclusive, as the effect may be dominated by observational biases.

432.05D – The 3.4 µm Extragalactic Background Light as Measured Using <i>WISE</i>

Sean E. Lake[1], Edward L. Wright[1], Sara M. Petty[2], Roberto J. Assef[3], Roc M. Cutri[5], S. A. Stanford[7], Daniel Stern[4, 6]
1. UCLA, Los Angeles, CA, United States. 2. Virginia Tech, Blacksburg, VA, United States. 3. Universidad Diego Portales, Santiago, Chile. 4. JPL, Pasadena, CA, United States. 5. IPAC, Pasadena, CA, United States. 6. CalTech, Pasadena, CA, United States. 7. UC Davis, Pasadena, CA, United States.

The extragalactic background light (EBL) beyond the cosmic microwave background (CMB) contains valuable information about the star formation history of the universe. The near- to mid-infrared background measurements (roughly 2—5 µm), with uncertainties in the contribution from the first stars, the accuracy of zodiacal light subtraction, and upper limits based on absorption of TeV gamma rays from blazar spectra that are lower than some measurements of the amount of light contributed by galaxies. Using WISE, we measured the 2.4 µm luminosity function of galaxies out to z = 1 and, extrapolating to low luminosity, used it to calculate the contribution of galaxies with z ≤ 1 to the 3.4 µm EBL. This marks an improvement over previous efforts to measure this contribution that relied on extrapolating flux counts because it relies on the more physically motivated luminosity function. The luminosity function is also improved over previous efforts in this wavelength range by both improved sensitivity and large N statistics from utilizing large public spectroscopic redshift surveys.

432.06 – Implications for Galaxy Evolution Inferred from Virial-Mass Self-Similarity of the Circumgalactic Medium

Christopher W. Churchill[1], Nikole M. Nielsen[1], Glenn Kacprzak[2]
1. New Mexico State Univ., Las Cruces, NM, United States. 2. Swinburne University of Technology, Hawthorn, VIC, Australia.

Drawing from the MgII-Absorbing Galaxy Catalog (MAGIICAT, Neilsen etal 2013), we studied the circumgalactic medium (CGM) for a sample of ~180 z<1 galaxies. We determined the galaxy halo masses (dark matter + baryons) using halo abundance matching to the Bolshoi simulations. We find that the circumgalactic medium, observed in cool/warm (4.5 < logT <5) [K] metal enriched gas, is characterized by a universal projected profile in both the strength of absorption and the covering fraction of the cool/warm gas as a function of projected galactocentric distance, D, once D is normalized by the the

virial radius, Rvir, of the host galaxy halo. This indicates that, in the 200 kpc extended regions surrounding galaxies, cool/warm CGM gas exhibits self-similar behavior with virial mass. On average, at a given location D/Rvir, the optical depth and or kinematic spread of the gas, AND the volume filling factor of the gas is the same in low mass halos and high mass halos. Since the CGM is a substantially massive reservoir of baryonic gas, and is the conduit through which ISM gas is replenished, stellar driven galactic winds flow and recycle, and filaments and merging minor galaxies accrete, this observed self-similar behavior places meaningful observational constraints on the gas cycles that regulate galaxy evolution. For example, we discuss how the stellar mass- ISM metallicity relationship for galaxies and the self-similar behavior of the CGM components of galaxies indicate a symbiosis of the physical process acting on very different spatial scales within galaxies.

433 – Star Clusters and Associations, Galactic and Extragalactic

Oral Session – National Harbor 2 – 09 Jan 2014 02:00 pm to 03:30 pm

433.01 – Modelling of Proper Motions in Globular Clusters

Laura Watkins[1], Andrea Bellini[1], Roeland P. Van Der Marel[1], Jay Anderson[1]
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Contributing teams: HSTPROMO

Globular clusters come in a variety of flavours; their different components and different evolution histories leave imprints on their internal dynamics, which makes dynamical modelling a valuable tool for understanding their properties. Velocity dispersion profiles and mass profiles are key when investigating energy equipartition and core collapse or when hunting for intermediate mass black holes. Proper motion data are particularly useful as they provide two velocity components, which allows us to determine anisotropy profiles as well. From analyses by Bellini et al. carried out in the context of the HST Proper Motion (HSTPROMO) collaboration we now have HST proper motion data for some two dozen Galactic globular clusters. Each dataset typically contains proper motion data with accuracies of order 1 km/s for tens of thousands of stars within the central arcminute. We have developed new modelling techniques specifically designed to work with large, high-quality, discrete datasets of this nature, which we have successfully tested and applied to omega Centauri. We will briefly discuss our modelling efforts and then present some preliminary results for the new HST datasets, including velocity dispersion profiles, mass profiles, and energy equipartition.

433.02 – Mass segregation for the young star clusters

Jincheng YU[1]
1. Pontificia Universidad Católica de Chile, Santiago, Metropolitan Region, Chile.

Mass segregation of the young star cluster is one of the dynamical properties which is an important tool to investigate the star forming process and dynamical evolution of star clusters. The origin of this mass segregation has been suggested as either "primordial," that is, it is a result of the star formation process in which stars form mass segregated from their parent molecular cloud, or dynamical, i.e., resulting from fast dynamical evolution. Recent N-body simulations suggest initially dynamically cool and sub-structured star clusters can be mass segregated within very short timescale. However, the effects of different initial conditions are still not well understood. Therefore, we investigate the influence of different initial parameters to further constrain our theoretical model for young star clusters. We will show rapid dynamical mass segregation exist not only in low-mass star clusters but also the massive star clusters. In particular, we focus on the correlation between the fractality and the degree of mass segregation of the early evolution of young star clusters.

433.03D – Abundances of Local Group Globular Clusters Using High Resolution Integrated Light Spectroscopy

Charli Sakari[1], Andrew McWilliam[2], Kim Venn[1], Matthew D. Shetrone[3], Aaron L. Dotter[4], Dougal Mackey[4]
1. University of Victoria, Victoria, BC, Canada. 2. The Observatories of the Carnegie Institute of Washington, Pasadena, CA, United States. 3. McDonald Observatory, University of Texas at Austin, Fort Davis, TX, United States. 4. Research School of Astronomy and Astrophysics, The Australian National University, Weston, ACT, Australia.

Abundances and kinematics of extragalactic globular clusters provide valuable clues about galaxy and globular cluster formation in a wide variety of environments. In order to obtain such information about distant, unresolved systems, specific observational techniques are required. An Integrated Light Spectrum (ILS) provides a single spectrum from an entire stellar population, and can therefore be used to determine integrated cluster abundances. This dissertation investigates the accuracy of high resolution ILS analysis methods, using ILS (taken with the Hobby-Eberly Telescope) of globular clusters associated with the Milky Way (47 Tuc, M3, M13, NGC 7006, and M15) and then applies the method to globular clusters in the outer halo of M31 (from the Pan-Andromeda Archaeological Survey, or PAndAS). Results show that: a) as expected, the high resolution method reproduces individual stellar abundances for elements that do not vary within a cluster; b) the presence of multiple populations does affect the abundances of elements that vary within the cluster; c) certain abundance ratios are very sensitive to systematic effects, while others are not; and d) certain abundance ratios (e.g. [Ca/Fe]) can be accurately obtained from unresolved systems. Applications of ILABUNDS to the PAndAS clusters reveal that accretion may have played an important role in the formation of M31's outer halo.

433.04 – Wide-Field HST Observations of the Globular Cluster System in NGC 1399

Thomas H. Puzia[1]

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Contributing teams: Maurizio Paolillo, Paul Goudfrooij, Thomas J. Maccarone, Giuseppina Fabbiano, Lorella Angelini

We present a comprehensive high spatial-resolution imaging study of globular clusters (GCs) in NGC 1399, the central giant elliptical cD galaxy in the Fornax galaxy cluster, obtained with HST/ACS. Using a novel technique to construct drizzled PSF libraries for HST/ACS data, we accurately determine the GC half-light radius, r_h, for the major fraction of the NGC 1399 GC system and find a trend of increasing r_h versus galactocentric distance, R_{gal}, out to ~10 kpc and a flat relation beyond. This trend is very similar for blue and red GCs which are found to have a mean size ratio of $r_h(red)/r_h(blue)=0.82+/-0.11$ at all R_{gal} from the core regions of the galaxy out to ~40 kpc. This suggests that the size difference between blue and red GCs is due to internal mechanisms related to the evolution of their constituent stellar populations. Modeling the stellar mass density profile of NGC 1399 derived from its surface brightness profile shows that additional external dynamical mechanisms are required to limit the GC size in the galaxy halo regions. We suggest that this may be realized by an exotic GC orbit distribution function, an extended dark matter halo, and/or tidal stress induced by the increased stochasticity in the dwarf halo substructure at larger galactocentric radii. We compare our results with the GC r_h distribution functions in various galaxies and find that the fraction of extended GCs is systematically larger in late-type galaxies compared with GC systems in early-type galaxies. This is likely due to the dynamically more violent evolution of early-type galaxies. We match our GC r_h measurements with radial velocity data from the literature and split the resulting sample at the median r_h value into compact and extended GCs. We find that compact GCs show a significantly smaller line-of-sight velocity dispersion, 225+/-25 km/s, than their extended counterparts, 317+/-21 km/s. Considering the weaker statistical correlation in the GC r_h-color and the GC r_h-R_{gal} relations, the more significant GC size-dynamics relation appears to be astrophysically more relevant and hints at the dominant influence of the GC orbit distribution function on the evolution of GC structural parameters.

433.05 – Stellar clusters formed from debris of colliding galaxies

Duilia F. De Mello[1], Claudia Mendes de Oliveira[2], Sergio Torres-Flores[3], Fernanda Urrutia-Viscarra[2, 4]

1. Catholic University of America, Washington, DC, United States. 2. IAG/USP, Sao Paulo, SP, Brazil. 3. Univ. de La Serena, La Serena, Chile. 4. ESO, Garching, Germany.

When galaxies collide they leave behind debris in the intergalactic medium. In this presentation I will summarize the latest results in our quest searching for stars formed within these debris. We searched for GALEX UV sources within HI tails of 33 interacting systems and have examined several of them in detail with Gemini 8m telescope. We find a variety of sources ranging from small stellar clusters, to precursors of globular clusters and tidal dwarf galaxies. The high metallicity (at least solar) of these young systems suggests that they were formed in situ with pre-enriched material. We suggest that interacting systems are good laboratories for producing intergalactic systems that may be responsible for polluting the intergalactic medium.

433.06 – De-confusing Herschel images by using bayesian priors.

Mohammadtaher Safarzadeh[1], Henry C. Ferguson[2], Yu Lu[3], Hanae Inami[4], Mark Dickinson[4], David Elbaz[5]
1. The Johns Hopkins University, Baltimore, MD, United States. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. Stanford University, Stanford, CA, United States. 4. NRAO, Tucson, AZ, United States. 5. Laboratoire AIM-Paris-Saclay, Paris, Paris, France.
Contributing teams: The CANDELS, GOODS-Herschel, CANDELS-Herschel collaborations

Deep observations of sky by PACS instrument on board of Herschel Telescope at 160 μm are limited by confusion noise. Fluctuations in background flux due to undetected sources together with a high number of beams per source are the limiting factor for detecting faint sources. We have investigated the possibility of de-confusing Herschel PACS160 μm images by using strong Bayesian priors on the positions and weak priors on the fluxes of sources. Our investigation uses a semi-analytical model (SAM) to simulate PACS160 μm image with galaxies positions, redshift, and 1.6 μm fluxes being close to the observed galaxies in the HST CANDELS images of the GOODS-S field (but with spectral-energy distributions that are otherwise unconstrained by the data). Simulated Herschel images are created with the "true" fluxes from the SAM, and we attempt to recover the fluxes using their exact known positions and a several-dex wide top-hat prior on their Herschel fluxes. A Monte Carlo Markov Chain method is used to derive the posterior probability density of fluxes subject to these priors. The simulations show great promise for extracting useful photometry for sources fainter than the current confusion limit of 0.7 mJy. This technique could in principle be used to mitigate the effects of source confusion in any situation where one has prior information on positions and plausible fluxes of blended sources. For Herschel, application of the technique will improve our ability to constrain the dust content in normal galaxies at high redshift.

434 – Stellar Evolution II
Oral Session – Potomac Ballroom C – 09 Jan 2014 02:00 pm to 03:30 pm

434.01D – The Mass-Transfer Formation of Blue Stragglers as Revealed by their White Dwarf Companions

Natalie M. Gosnell[1]

1. University of Wisconsin-Madison, Madison, WI, United States.

The formation mechanism of blue straggler stars, defined to be brighter and bluer than the main sequence turnoff in a star cluster, has been a question for almost six decades. The blue straggler population of the old (7 Gyr) open cluster NGC 188 provides a unique opportunity to probe the formation histories of blue straggler stars in open clusters. In comparison to the blue straggler populations in younger open clusters and in globular clusters, the cooler temperatures (6,000 to 6,750 K) and close proximity (2.5 kpc) of the blue stragglers in NGC 188 allow for in-depth high-resolution spectroscopic investigation. Long-term radial velocity studies revealed that over 75% of the NGC 188 blue stragglers exist in binaries with a prevalence of 1000-day periods and a statistical secondary mass distribution that peaks at 0.5 Msolar. Using HST/SBC far-UV photometry I will present direct observational detections of young (<300 Myr), hot white dwarf companions in three blue straggler binaries. Given the age distribution predicted in full N-body models, which translates into a white dwarf temperature distribution, three detections is consistent with the entire NGC 188 blue straggler population being formed via mass transfer. These detections affirm the prediction made by previous studies that the blue straggler population of NGC 188 is dominated by mass transfer formation. I also identify and present specific initial binaries and pathways through which these three binary systems could have formed. Support for Program number 12492 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555.

434.02 – Carbon Stars in Andromeda. I. Detection and Spectroscopic Properties

Katherine Hamren[1], Elisa Toloba[1, 3], Claire Dorman[1], Puragra Guhathakurta[1], Matthew Chang[2], Sumedh Guha[4]

1. University of California Santa Cruz, Santa Cruz, CA, United States. 2. Mountain View High School, Mountain View, CA, United States. 3. OCIW, Pasadena, CA, United States. 4. Yale University, New Haven, CT, United States.

Contributing teams: PHAT collaboration, SPLASH collaboration

We present a sample of carbon stars in the Andromeda galaxy (M31) and their spectra. As part of the SPLASH survey, and in conjunction with the PHAT survey, spectra were obtained for ~10,000 stars in M31 using the Keck II 10-m telescope and DEIMOS spectrograph. We identify carbon stars within this sample with a combination of automated detection and visual confirmation. We have found a few hundred carbon stars, which amount to a few percent of the total SPLASH sample. We designate these carbon stars "strong", "weak" or "marginal" based on the prominence of the absorption feature at 7900 Angstroms. We explore trends in these groups of spectra as a function of color. We find that carbon stars are remarkably invariant with color, particularly in comparison to the M giants that make up the majority of the SPLASH sample. This research is part of two large collaborations: the PHAT collaboration and the SPLASH collaboration. Our project is funded by the National Science Foundation and NASA.

434.03 – Carbon Stars In Andromeda. II. Demographics and Photometric Properties

Puragra Guhathakurta[1], Katherine Hamren[1], Claire Dorman[1], Elisa Toloba[1, 5], Anil Seth[2], Julianne Dalcanton[3], Avinash Nayak[4]

1. UC, Santa Cruz, Santa Cruz, CA, United States. 2. Univ of Utah, Salt Lake City, UT, United States. 3. Univ of Washington, Seattle, WA, United States. 4. Harker School, San Jose, CA, United States. 5. OCIW, Pasadena, CA, United States.

Contributing teams: PHAT collaboration, SPLASH collaboration

This is the second of two talks about a sample of newly-discovered carbon stars in the Andromeda galaxy (M31). As explained in the first talk, these stars were identified on the basis of their spectroscopic characteristics using Keck/DEIMOS spectra obtained as part of the Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo (SPLASH) survey. We explore the physical properties of strong and weak carbon stars using photometric data from a Hubble Space Telescope Multi-Cycle Treasury program: Panchromatic Hubble Andromeda Treasury (PHAT). The PHAT data set includes deep photometry in six filters: two in the ultraviolet, two in the optical, and two in the near infrared. The carbon stars appear to be in the asymptotic giant branch stage of their evolution as evidenced by the fact that they lie above the tip of the red giant branch and are cleanly separated from normal (i.e., oxygen-rich) giants in color-magnitude diagrams. We study the spatial distribution of

carbon stars in M31 and use kinematics to determine whether they belong to M31's thin disk, thick disk, or spheroid. These carbon stars serve as highly visible tracers of the intermediate-mass, intermediate-age stellar population in M31; they are important markers in the study of the star-formation history of the galaxy. This research was part of the SPLASH and PHAT collaboration. We are grateful to the National Science Foundation and NASA for funding support. AN's participation was under the auspices of UCSC's Science Internship Program.

434.04 – Nonadiabatic Pulsation Analysis of Supermassive Stars

Christopher J. White[1], Jeremy Goodman[1]
1. Astrophysical Sciences, Princeton University, Princeton, NJ, United States.

We implement a nonadiabatic linear perturbation analysis on models of very massive stars in order to determine their stability against radial disruption. Rather than employing adiabatic work integrals, we find growth rates via the imaginary components of the eigenvalues. We apply this to Population III models as well as to high-metallicity models extending up to about 1000 solar masses. According to our results the traditional ?- and ε-mechanisms are insufficient to cause catastrophic disruption of these stars on timescales shorter than their main sequence lifetimes.

434.05 – Fast or Slow? The Implications of Core Rotation Measurements for Stellar Angular Momentum Evolution

Marc H. Pinsonneault[1], Jamie Tayar[1]
1. Ohio State Univ., Columbus, OH, United States.

Asteroseismology now permits the measurement of core rotation rates in evolved stars. Strong differential rotation sets in during the first dredge-up for red giants and is suppressed in the core-He burning phase. This data complements constraints on core-envelope coupling from the Sun and the spin down of young cluster stars. The implications for diagnosing the dominant angular momentum transport mechanisms in stars are discussed.

434.06 – Studying Magnetic Fields in Young Stellar Objects with MoogStokes

Casey Deen[1], Daniel T. Jaffe[2], Wolfgang Brandner[1], Christopher M. Johns-Krull[3]
1. Max Planck Institut für Astronomie, Heidelberg, Baden-Würtemberg, Germany. 2. University of Texas, Austin, TX, United States. 3. Rice University, Houston, TX, United States.

Timescales for star and planet formation derive from comparisons of the observed positions of young clusters in the HR diagram with theoretical isochrones. While there are many reasons to expect an intrinsic scatter in the HR diagram (initial conditions, accretion histories, duration of star formation), for the youngest clusters, the act of determining effective temperatures and luminosities is fraught with uncertainty. Using MoogStokes, a polarized radiative transfer code, to account for the effects of magnetic fields on the emergent spectra, we show that strong magnetic fields (of the strengths measured in young stellar objects) can significantly alter the appearance of the spectrum. Neglecting the effect of the magnetic field when determining properties of the young object (spectral type and luminosity) will artificially shift the location of the object in the HR diagram, biasing any statistics derived from a population of young objects. By properly accounting for the effects of the magnetic field, it is possible to a) properly place objects on the HR diagram, and b) measure magnetic field strengths in young objects

435 – The Exciting Future of Cosmic Microwave Background Measurements

Special Session – Potomac Ballroom D – 09 Jan 2014 02:00 pm to 03:30 pm

Measurements of the cosmic microwave background (CMB) have produced tight constraints on cosmological parameters; provided insights into inflation; and enabled sensitive tests for extensions beyond the standard six parameter cosmological model. While measurements of the temperature angular power spectrum are approaching the cosmic variance limit, CMB instrumentation has progressed to the point where faint new signals are now accessible. In polarization the CMB may encode a detectable signal from the imprint of a background of gravitational waves Produced by inflation moments after the Big Bang. In addition, polarization can probe the weak gravitational lensing of the CMB which represents a new cosmological tool for measuring large scale structures, which are sensitive to neutrino mass, early dark energy, and galaxy formation in combination with multi-wavelength surveys. Recently the Planck satellite provided spectacular measurements over the entire sky and over a frequency range between 30 and 857 GHz, and in 2014 Planck will release new polarization data. A new generation of receivers with higher sensitivity than Planck, enabled by rapid advances in detector technology, are pushing CMB polarization measurements to very low levels from ground-based and sub-orbital platforms. Improvements to instrumentation over the past quarter century also provide an avenue to improve our understanding of the CMB blackbody spectrum by three orders of magnitude beyond the 50 parts-per-million accuracy to which it was measured by COBE, the Cosmic Background Explorer. A new experiment could detect distortions at this level providing new constraints on processes ranging from inflation and the nature of the first stellar objects to exotic phenomena including primordial black holes, cosmic strings, and the decay or annihilation of dark matter. In this session we review the current state of the CMB field and offer a roadmap for upcoming results and ambitious future instruments.

435.01 – Planck and the State of the Art in CMB Measurements

Charles R. Lawrence[1]
1. JPL, Pasadena, CA, United States.

I will review what Planck has done, what it will do in the future, and useful lessons from Planck relevant for future CMB measurements.

435.02 – What we know and what we don't know about the CMB spectrum

John C. Mather[1]
1. NASA's GSFC, Greenbelt, MD, United States.
Contributing teams: COBE team, PIXIE team

To a precision of 50 ppm, the Cosmic Microwave Background Radiation has a blackbody spectrum with a temperature of 2.725 K, at wavelengths from 0.5 to 5 mm. This measurement by the COBE satellite team confirmed the concept of an expanding universe that was extremely hot and dense when it was young. In this picture, the CMB spectrum could be slightly distorted from the blackbody form by energy release or conversion after the universe was a few months old. At that time, the interaction of photons and electrons became weak enough that photons could no longer be easily created or destroyed, so that energy added or subtracted from the CMB would result in a spectrum with a chemical potential (mu distortion). Later, Compton scattering became incapable of equilibrating the spectrum to the chemical potential form, leading to a possibility of a mixture of blackbodies at different temperatures (y distortion). So far, there are only upper limits on the y and mu distortions, setting limits on possible sources of energy release such as the dissipation of acoustic modes at small scales, the decay of WIMPs, the action of primordial black holes, etc. On the other hand, the CMB spectrum is not expected to follow a blackbody to arbitrary precision. Energy releases associated with various astrophysical processes (recombination, reionization, and structure formation) will inevitably distort the CMB spectrum to create y or mu distortions at potentially observable amplitudes. Improved instrumentation capable of detecting such distortions could open a new window into the early universe, providing new constraints on processes ranging from inflation and the nature of the first stellar objects to exotic phenomena including primordial black holes, cosmic strings, and the decay or annihilation of dark matter.

435.03 – Cosmic Microwave Background as a Probe of the Low Redshift Universe

David N. Spergel[1]
1. Princeton Univ. Obs., Princeton, NJ, United States.

As microwave background photons propagate from the surface of last scatter to our telescopes, they are effected by intervening matter. Through gravitational lensing, the thermal Sunyaev-Zeldovich effect (tSZ) and the kinematics Sunyaev-Zeldovich effect (kSZ), matter alters the appearance of the CMB sky. Over the past few years, cosmologists using ACT, SPT and Planck have detected these effects both through cross-correlations and measurements of higher point statistics. I will review how these observations measure the density, pressure and momentum in the intervening material and then look forward to upcoming observations.

435.04 – Constraints on Inflation from Polarization and CMB Spectral Distortions

Marc Kamionkowski[1]

1. Johns Hopkins University, Baltimore, MD, United States.

This talk will summarize some things we can do with future CMB experiments to study the early Universe. An obvious first is to map the polarization from density perturbations to the cosmic-variance limit to improve upon the types of things (cosmological-parameter determination, lensing, etc.) that have been done so far with the temperature. Another direction, which already has considerable momentum, is the pursuit of the characteristic polarization signature of inflationary gravitational waves. But there is also a strong case, which I will review, now being assembled for a space mission to seek the tiny but nonzero departures from a blackbody spectrum that are expected in the standard cosmological model and that may arise from several interesting exotic mechanisms.

435.05 – The Once and Future Signal: CMB Science from Sub-orbital and Proposed Satellite Missions

Alan J. Kogut[1]

1. NASA's GSFC, Greenbelt, MD, United States.

In the nearly 50 years since the identification of an isotropic radio residual as the cosmic microwave background, experimental precision has increased by 6 orders of magnitude. A new generation of instruments is poised to provide another 2--3 orders of magnitude improvement in measurements of the CMB temperature anisotropy, polarization, and blackbody spectral distortions. Measurements at this sensitivity should provide a wealth of new information on the content, structure, and evolution of the universe. This talk will survey the fast-developing field of CMB experiments, and conclude with the science return possible from an ambitious set of balloon-borne and proposed satellite missions.

435.06 – Latest CMB Measurement Results

James Bock[1]

1. Caltech, Pasadena, CA, United States.

We have allocated time in this special session to capture the latest developments in balloon-borne and ground-based CMB measurements. The speaker for this oral presentation will be chosen at a later date in order to best highlight emerging results. This session also includes presentations from current CMB experiments in a parallel poster session. Time-permitting, the latest community plans for future CMB measurement facilities may also be discussed.

436 – Young Stellar Objects II
Oral Session – National Harbor 4 – 09 Jan 2014 02:00 pm to 03:30 pm

436.01 – Magnetically Aligned Dust Grains in Young Stellar Objects

Erica Rodgers[1], Angela Cotera[2], Barbara Whitney[1, 3]
1. Space Science Institute, Boulder, CO, United States. 2. SETI, Avondale, AZ, United States. 3. University of Wisconsin - Madison, Madison, WI, United States.

Young stellar objects (YSOs) evolve from being dominated by a circumstellar envelope, which overtime collapses onto a circumstellar disk and disperses via jets and outflows, while the disk material accretes onto the forming star. Planets form in the circumstellar disks from dust grains that begin with an interstellar medium (ISM) grain size distribution, and grow from sizes typically less than 1um to planets with radii greater than 6000 km. Light from the forming central star scatters off of the small dust grains in the disk, envelope and outflow regions resulting in polarization at near-infrared wavelengths. Studying the polarized light in these regions provides insight into the size and distribution of the dust grain population, which changes as the YSO evolves; thus facilitating our understanding of both stellar and planetary formation. We model high-resolution Hubble Space Telescope Near Infrared Camera and Multi-Object Spectrometer (NICMOS) imaging and polarimetry for a group of four (IRAS04302+2247, IRAS04016+2610, CoKu Tau/1, DG Tau B) Taurus-Auriga YSOs known to span the earliest stellar evolutionary phases. We use both well-developed 3-D radiative transfer codes and magnetically aligned non-spherical dust grain models to predict imaging and polarimetry. We simultaneously fit multi-wavelength (submicron to millimeter) spectral energy distributions (SEDs) for our YSOs to further constrain the model results. We present data and model imaging, polarimetry and SED comparisons using magnetically aligned non-spherical dust grains in varying magnetic field geometries. Dichroic scattering and extinction by magnetically aligned non-spherical grains may lead to significant polarization in circumstellar environments as compared to scattering from spherical grains, which were the focus of our previous research effort. Radiative transfer models of our four YSOs indicate that spherical dust grains do not produce as much polarization as is observed by NICMOS. Therefore, we seek to better understand the significance of magnetically aligned gains in the polarization production, as we anticipate these non-spherical grains may be a better representation of circumsteller environments.

436.02 – HST FUV monitoring of TW Hya

Hans Guenther[1], Nancy S. Brickhouse[1], Andrea K. Dupree[1], Gerardo Luna[1, 3], Peter C. Schneider[2], Scott J. Wolk[1]
1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 2. Hamburger Sternwarte, Hamburg, Germany. 3. Instituto de Astronomia y Fisica del Espacio, Buenos Aires, Argentina.

Classical T Tauri stars (CTTS) show strong, broad and asymmetric FUV emission lines. Neither the width, nor the line profile is understood. Likely, different mechanisms influence the line profile; the best candidates are accretion, winds and stellar activity. We monitored the C IV 1548/1550 Å doublet in the nearby, bright CTTS TW Hya to correlate it with i) the cool wind, as seen in COS NUV Mg II line profiles, ii) the photometric period from joint ground-based monitoring, iii) the accretion rate as determined from the UV continuum and iv) the Ha line profile from independent ground-based observations. The observations span 10 orbits distributed over a few weeks to cover the typical time scales of stellar rotation, accretion and winds. On short time scales (seconds) the variability in the data is compatible with counting statistics when we take certain instrumental effects (the detector dead-time fraction increases when the wavelength calibration lamps are switched on). This rules out any type of coherent accretion shock fluctuation as predicted in some simulations. On longer time scales (days) variability of a factor of 3 in the continuum and similarly massive changes in the line shape are seen. The ratio of the two lines of the doublet indicates that the lines are optically thick, calling into question the idea that the blue-shifted components of the C IV lines are formed in the pre-shock region.

436.03 – Massive Stellar Outflows From the Combined Action of Multiple Stellar Jets

Mordecai-Mark Mac Low[1, 4], Thomas Peters[2], Pamela Klaassen[3], Martin Schrön[4, 5], Ralf Klessen[4]
1. American Museum of Natural History, New York, NY, United States. 2. Universität Zürich, Zürich, Switzerland. 3. Universiteit Leiden, Leiden, Netherlands. 4. Universität Heidelberg, Heidelberg, Germany. 5. Helmholtz Zentrum für Umweltforschung, Leipzig, Germany.

The formation of high-mass stars is usually accompanied by powerful protostellar outflows. Such high-mass outflows are not simply scaled-up versions of their lower-mass counterparts, since observations seem to suggest that the collimation degree degrades with stellar mass. Theoretically, the origins of massive outflows are not well understood because radiative feedback and gravitational fragmentation of the accretion flow around the high-mass star impede the driving of magnetic disk winds. We here present the first 3D simulation of massive star formation that simultaneously includes feedback by non-ionizing and

ionizing radiation as well as a subgrid-scale model for protostellar outflows. We ran this model with the Flash adaptive mesh refinement hydrocode. We find that stars that form in a common accretion flow have aligned outflow axes, so that the individual jets of lower-mass companion stars combine to form a collective outflow. We compare our simulation to observations with synthetic H2 and CO observations and find that the morphology and kinematics of this collective outflow is very similar to observed massive outflows, such as Cepheus A and DR 21. The properties of high-mass outflows are therefore generally consistent with the formation of massive stars in gravitationally unstable accretion flows.

436.04D – Powerful jets driven by intermediate-mass protostars in the Carina Nebula

Megan Reiter[1], Nathan Smith[1]
1. The University of Arizona, Tucson, AZ, United States.

The Carina nebula hosts the largest known population of powerful HH jets driven by intermediate-mass stars in a single region. These jets are externally irradiated by dozens of O-type stars in Carina that illuminate unshocked material in the jet, allowing for a more complete census of the mass-loss. Despite the strong incident ionizing radiation, portions of these jets remain neutral. Near-IR [Fe II] images reveal dense, neutral gas that was not seen in previous studies of Hα emission. We show that near-IR [Fe II] emitting gas must be self-shielded from Lyman continuum photons, regardless of its excitation mechanism (shocks, FUV radiation, or both). High densities are required for the survival of Fe+ amid the strong Lyman continuum luminosity from Tr14, raising estimates of the mass-loss rates by an order of magnitude. New proper motion measurements using Halpha images with a ~4.25 year baseline reveal tangential velocities of >200 km/s, in some cases exceeding velocities typical for jets from low-mass stars. In addition, these outflows are highly collimated, with opening angles of only a few degrees, similar to low-mass protostars. We propose that these jets reflect essentially the same outflow phenomenon seen in low-mass protostars, but that the collimated atomic jet core is irradiated and rendered observable. Thus, the irradiated jets in Carina constitute a new view of jets from intermediate-mass protostars that demonstrate that they are as collimated as their low-mass counterparts, but support higher densities and velocities, leading to higher mass-loss rates. This scaling of phenomena seen in low-mass star formation offers strong additional evidence that stars up to ~8 Msun form by the same accretion mechanism as low-mass stars.

436.05D – Cep OB3b: A Multi-Wavelength Survey of a Nearby Rich Young Stellar Cluster

Thomas Allen[1], S. Thomas Megeath[1], Jakub Prchlik[3], Robert A. Gutermuth[7], Judith Pipher[2], Tim Naylor[4], Rob Jeffries[5], Scott J. Wolk[6]
1. University of Toledo, Toledo, OH, United States. 2. University of Rochester, Rochester, NY, United States. 3. Case Western, Cleveland, OH, United States. 4. University of Exeter, Exeter, United Kingdom. 5. Keele University, Keele, United Kingdom. 6. Center for Astronomy, Cambridge, MA, United States. 7. University of Massachusetts, Amherst, MA, United States.

We present results from an extensive multi-wavelength survey of Cep OB3b, one of the largest young clusters within 1 kpc of the Sun. We estimate that Cep OB3b has a membership of approximately 3000 young stars in a region of 10 x 7 pc (Allen et al. 2012). Similar in membership and overall size to the ONC, Cep OB3b is older and more evolved, with most of the young stars located in a cavity with a V-band extinction of less than 2.5 magnitudes. Star formation is still occurring in the molecular clouds that border the cavity. Literature age estimates for this region give a range between 3-6 Myr (Mayne et al. 2007, Littlefair et al. 2010, Bell et al. 2013). We have compiled an extensive multi-wavelength database including new observations from Spitzer, Chandra and Hectospec on the MMT; with these data we can characterize the spectral types, bolometric luminosities, masses, isochronal ages, X-ray properties and the presence (or lack) of a disk for clusters members. To construct a precise HR diagram for ~650 cluster members, we derive an extinction law for this region between 500 nm and 2.2 um and find it intermediate between that of dense clouds (R~5) and that of the diffuse ISM (R~3). Using the Baraffe (1998) models and assuming a distance of 700 pc give an isochronal age of 3 Myr. We find that certain cluster properties, such as the disk fraction and rotation period distribution, vary spatially across the cluster. We analyze whether these variations are due to environmental differences (such as nearby massive O stars) or a mixture of ages in the cluster. In the case of the disks, we conclude that the variations are due to a mixture of ages.

437 – AIP Gemant Award Lecture: Star Trek: The Search for the First Alleged Crab Supernova Rock Art

Plenary Session – Potomac Ballroom A – 09 Jan 2014 03:40 pm to 04:30 pm

437.01 – Star Trek: The Search for the First Alleged Crab Supernova Rock Art

E. C. Krupp[1]

1. Griffith Obs., Los Angeles, CA, United States.

Since the 1950s, star/crescent combinations in prehistoric rock art in the American Southwest have become broadly accepted as eyewitness records of the Crab supernova explosion, a spectacular event visible in 1054 A.D. For more than three decades, images of this "supernova" rock art have routinely appeared in astronomy textbooks, in popular articles, on websites, and in television programs. As this Crab supernova interpretation became more fashionable, Griffith Observatory Director E.C. Krupp began a long-term effort to inspect each of these sites in person. His field work eventually led him, in 2008, to the two sites in northern Arizona that started this cottage industry in supernova rock art, sites that had been lost and had not been revisited for 50 years. Developments in the study of rock art, Pueblo Indian iconography, and Pueblo ceremonialism have permitted a greater appreciation of the role of the sky in the ancient Southwest. The best known star/crescent sites are surveyed to clarify the discipline required for cross-disciplinary research. Through this exploration of an aspect of the relationship between astronomy and culture, the presentation acknowledges the intent of American Institute of Physics Andrew Gemant Award.

460 – Berkeley Prize: Using the SDO Atmospheric Imaging Assembly to Study Solar Activity

Plenary Session – Potomac Ballroom A – 09 Jan 2014 04:30 pm to 05:20 pm

460.01 – Using the SDO Atmospheric Imaging Assembly to Study Solar Activity

James Lemen[1]

1. Lockheed Martin Solar & Astrophysics Lab, Palo Alto, CA, United States.

The Atmospheric Imaging Assembly (AIA) is one of the instruments on board NASA's flagship Solar Dynamics Observatory (SDO) mission that was launched in February 2010. AIA achieves 1.5 arcsec spatial resolution of the entire solar corona with 12-second temporal resolution in seven extreme ultraviolet (EUV) band passes centered on specific lines: Fe XVIII (94 Å), Fe VIII, XXI (131 Å), Fe IX (171 Å), Fe XII, XXIV (193 Å), Fe XIV (211 Å), He II (304 Å) and Fe XVI (335 Å); one band pass observes C IV (near 1600 Å). In the past 3 years AIA has produced over 77M images and 1,200 Tbytes of data that have challenged and clarified our understanding of the solar corona, specifically how the solar magnetic field drives coronal evolution on various scales. Multi-temperature, low-noise, full-Sun observations have captured solar eruptions and flares, coronal field oscillations (in loops and filaments), fast-mode waves (up to 2,000 km/s), plasma instabilities, and a rare view of comet interactions with the corona. Comparison with data from other instruments, such as SDO EUV Variability Experiment (EVE), and with numerical models, provides the ability to develop a comprehensive understanding of solar activity and evolution. And the comparison of the information-rich spatial content of the AIA observations with EVE spectra is instructive for similar studies of stellar targets. The NASA heliophysics open-data policy enables wide-scale participation by the international community. As the time base of AIA observations and magnetic data obtained from the companion SDO Helioseismic and Magnetic Imager (HMI) increases to a good fraction of the solar dynamo cycle time scale, we anticipate that the value of the SDO data will be similarly magnified. We present highlights that have been gleaned from this already exceptional mission. http://sdowww.lmsal.com