219th AAS Meeting – Austin, TX January, 2011

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90 – HAD I: Transits of Venus: Looking Forward, Looking Back

Special Session – Room 12A – Sunday, January 8, 2012, 1:00 PM - 3:40 PM

The June 6, 2012, transit of Venus, completing the pair that began on June 8,2004, will represent the last chance to observe one of these rare events fromEarth until the next pair, December 11, 2117, and December 8, 2125. Thisyear's transit will be extremely advantageous as almost all the most populatedareas of the Earth will be able to see at least some of the transit: the only landmasses from which no part of the transit will be visible are the western Iberianpeninsula, the western part of Africa, the eastern part of South America, andAntarctica.

We invite presentations on both important historical aspects of the transits ofVenus and modern applications. From a historical point of view, the occasion is of importance in providing apoint of departure for a reconsideration of the singular importance of thetransits in the history of astronomy and in the geographical exploration of theEarth, which led to massive preparations and far flung expeditions in theeighteenth century in pursuit of the Halleyan project of determining the solarparallax. The nineteenth-century transits also played out against a backgroundrivalries among the great European world empires (England, Russia, France, andthe U.S.) then at their height and then sliding imperceptibly but ineluctablytoward the Great War. The 2012 transit offers an opportunity to revisit theimportant expeditions of the past—many of which have been catalogued andsome noted by markers or restored—and to engage in "experimentalarchaeology," the reconstruction of past observations, including of the BlackDrop and luminous aureole, about which it was and is often mistakenly statedthat, particularly for the earliest observations, it is produced by refraction by theatmosphere of Venus. Possible observations of special historical interest in2012 could include some using historical instruments and techniques orobserving from the same locations as earlier observers. But far from being anentirely retrospective exercise, the history of transit observations defines criticalproblems to be addressed by modern high-resolution observations from Earthand space. These include the detailed profiling of the atmosphere of Venus withground-based and space-based observations (from satellites meant to studythe Sun) and the study of a local analogue to exoplanet transits across theirparent stars, the focus of many contemporary astrophysical investigations andspace missions whose key astrophysical goals are to understand the prevalenceand structure of planetary systems very different from our own solar system. Inshort, though often said to be of strictly historical interest owing to the fact thatthe Halleyan solar parallax method has long since been superseded, transits ofVenus continue to be of great importance to astronomers and astrophysicistsworking at the cutting edge of important problems of our own day. See http://www.transitofvenus.info and http://www.transitofvenus.org.

90.01 – **Transits Of Venus: 1639, 1761, 1769, 1874, 1882, 2004, And 2012**

Jay M. Pasachoff[1]

[1]*Williams College.*

1:00 PM - 1:40 PM

Transits of Venus are exceedingly rare predictable astronomical events, with only six having been observed since Jeremiah Horrox corrected Johannes Kepler's Rudolphine Tables and observed the transit of 1639. Edmond Halley's 1716 method of finding the size and scale of the Solar System and thus of the Universe led to hundreds of 18th-century and 19th-century transit-of-Venus expeditions for each event. I discuss the history and importance of the transit observations, and how spacecraft observations of the 1999 transit of Mercury, repeated at the 2003 and 2006 transits, led to the solution of the black-drop effect problem that had prevented Halley's method from reaching its desired accuracy and thus solution of the noble problem of astronomy to find the size and scale of the solar system. Other spacecraft observations of the 2004 transit of Venus have led to an analysis of how Venus's atmosphere becomes visible for about 25 minutes before second contact and after third contact, and links with prior historical claims, mostly invalid, to have discovered Venus's atmosphere at transits. Total-solar-irradiance spacecraft observations at the 2004 Venus transit link to exoplanet discoveries with NASA's aptly named Kepler Mission and ESA's CoRoT. I further link previous transit observations to planned observations for the June 5/6, 2012, Venus transit and the May 9, 2016, Mercury transit, together providing a historical basis for 22nd-century astronomers preparing to observe the December 10, 2117, Venus transit.

My observations at the 2004 and 2012 transits of Venus were and will be supported in large part by grants from the Committee for Research and Exploration of the National Geographic Society. My solar observations were supported in part by NASA grant NNG04GK44G for work with the TRACE spacecraft and NASA Marshall grant NNX10AK47A and planetary work supported in part by NNX08AO50G from NASA Planetary Astronomy.

90.02 – **Astronomers, Transits of Venus, and the Birth of Experimental Psychology**

William Sheehan[1], S. Thurber

[1]*Child and Adolescent Behavioral Health Services.*

1:40 PM - 2:20 PM

The eighteenth century transits of Venus were regarded as the most important astronomical events of their era. Halley's expectation was that by observing the contact points between the limbs of Venus and the Sun, this distance could be determined to an accuracy of one part in 500. But in the event, it proved otherwise. But, as the British historian Agnes Clerke wrote in 1902: "A transit of Venus seems, at first sight, full of promise for solving the problem of the sun's distance. For nothing would appear easier than to determine exactly either the duration of the passage of a small, dark orb across a large brilliant disc, or the instant of its entry upon or exit from it⋯. But in that word 'exactly' what snares and pitfalls lie hid!" In the post-mortem analysis of the disappointing results, astronomers devoted a great deal of effort to understand the sources of errors. They rehearsed their observational techniques by observing, under strictly controlled conditions, transits of artificial planets across artificial Suns, and studied such parameters as attention and reflex reaction. In the process, the transits of Venus provided an important impetus to the early development of experimental psychology.

90.03 – **Australians and Americans: Observing the 1874 Transit Down Under**

Nick Lomb[1]

[1]*Powerhouse Museum, Australia.*

2:20 PM - 3:00 PM

Australia was one of the best places from which to observe in 1874 as the transit was visible, at least on the country's east coast, from beginning to end. All three state observatories, at Sydney, Melbourne and Adelaide, mounted observing campaigns. Their efforts were augmented by two American observing teams in Tasmania, one at Hobart led by the well-known U.S. Naval Observatory astronomer William Harkness and the other at Campbell Town that was there almost by there by accident.

In this talk I will tell the story of the Australian efforts plus those of the two American expeditions to Tasmania. The emphasis from the Australian observations will be on those of Sydney Observatory as out of that work came the book 'Observations of the transit of Venus, 9 December, 1874' by Henry Chamberlain Russell. The book has such excellent coloured illustrations that almost every popular article and book on the transit of Venus reproduces some of them. I will not only show examples of those illustrations, but also images of some of the original water colour illustrations found in the Observatory archives.

90.04 – **Transit of Venus Culture: A Celestial Phenomenon Intrigues the Public**

Chuck Bueter[1]

[1]*TransitOfVenus.org.*

3:00 PM - 3:40 PM

When Jeremiah Horrocks first observed it in 1639, the transit of Venus was a desirable telescopic target because of its scientific value. By the next transit of Venus in 1761, though, the enlightened public also embraced it as a popular celestial phenomenon. Its stature elevated over the centuries, the transit of Venus has been featured in music, poetry, stamps, plays, books, and art. The June 2004 transit emerged as a surprising global sensation, as suggested by the search queries it generated. Google's Zeitgeist deemed Venus Transit to be the #1 Most Popular Event in the world for that month. New priorities, technologies, and media have brought new audiences to the rare alignment. As the 2012 transit of Venus approaches, the trend continues with publicly accessible capabilities that did not exist only eight years prior. For example, sites from which historic observations have been made are plotted and readily available on Google Earth. A transit of Venus phone app in development will, if fully funded, facilitate a global effort to recreate historic expeditions by allowing smartphone users to submit their observed transit timings to a database for quantifying the Astronomical Unit. While

maintaining relevance in modern scientific applications, the transit of Venus has emerged as a cultural attraction that briefly intrigues the mainstream public and inspires their active participation in the spectacle.

91 – HAD II: Funding Astronomy in the Post-World War II Era

Special Session – Room 12A – Sunday, January 8, 2012, 4:00 PM - 6:00 PM

Thanks to the establishment of the National Science Foundation and the National Aeronautics and Space Administration in the United States, and various agencies in Europe and and Asia, there has been a massive influx of government funds into national and international astronomy during the last sixty-five years. At the same time, traditional sources of support, such as the Carnegie Institution of Washington, have continued to find their own niches in the new world of patronage. This session will explore the impact of the new patterns of patronage on astronomy in the United States and elsewhere.

91.01 – **Funding for Research in Astronomy Within and Beyond Japan Since WW II**

Sharon Traweek[1]

[1]*UCLA.*

4:00 PM - 4:25 PM

Japanese scientists have been quite resourceful in obtaining funding for research in astronomy projects within Japan and abroad. It is unusual in Japan for researchers to gain funding from more than one government agency. Several cases will be discussed, from the TRIPOD program of the Office of Development Assistance, begun in 1954, to the Subaru Telescope in Hawaii.

91.02 – **The Transformation of an Astronomical Institution**

David H. DeVorkin[1]

[1]*Smithsonian Inst..*

4:25 PM - 4:50 PM

In 1954 the Astrophysical Observatory of the Smithsonian Institution was closed down in Washington and transferred to Harvard, becoming the Smithsonian Astrophysical Observatory. It was a bureau of the Harvard College Observatory but was wholly governed by the Smithsonian in Washington. Historians such as the speaker and Ron Doel have explored the nature of the transfer, but not so much its implications. Specifically, soon after the transfer, the SAO geared up for the IGY, the only astronomical institution to do so in a big way, and the NSF became the conduit for a vastly increased level of activity of a character and scale only dreamed of by astronomers prior to the Cold War era. This support, and soon additional NASA and Air Force support, led to the SAO becoming one of the largest astronomical institutions on the planet by the mid-1960s. We will explore some of the implications.

91.03 – **European Astronomy in the Age of Space Research, 1964-1970**

Arturo Russo[1]

[1]*University of Palermo, Italy.*

4:50 PM - 5:15 PM

When the European Space Research Organization (ESRO) was established (1964) its long-term programme included two large satellites for astronomical studies. The first, called the Large Astronomical Satellite (LAS), would be devoted to high resolution ultraviolet spectroscopy of stars. Following a learning phase mainly devoted to small or medium-size satellites, this project was considered as the kind of costly and complex venture which provided ESRO with its raison d'être. The LAS, however, did not succeed in finding its way to the launch pad. Three main factors contributed to the abandonment of the project. Firstly, the dramatic escalation of its costs; secondly, the technical difficulty of the instrument designed by a British team from Culham Laboratory; thirdly, the strong competition between the various interest groups within the European space science community, which saw the astronomers in a weak position against the active community of physicists interested in magnetospheric studies, cosmic rays and high energy astrophysics. A smaller and less ambitious version of the LAS was submitted in 1969 in the competitive process for the selection of ESRO's new satellite. Here again the astronomy community lost. The ultraviolet space telescope, in fact, was discarded in favour of two space missions devoted to magnetospheric studies and gamma-ray astronomy, respectively. One year later, ESRO's Launching Programme Advisory Committee (LPAC) recognized that Europe could not afford to pursue all fields of space research, and recommended that stellar astronomy, solar physics and planetary research should be excluded in future planning. The 1970 policy statement established guidelines for the European space science programme for more than a decade. In this period, however, European astronomers had access to space technologies thanks to ESRO's contribution to the successful International Ultraviolet Explorer (IUE) mission, a NASA/UK project based on the UV telescope originally designed for the ill-fated ESRO project.

91.04 – **The National Science Foundation Revolutionizes American Astronomy, 1950-1975**

Marc Rothenberg[1]

[1]*NSF.*

5:15 PM - 5:35 PM

The National Science Foundation (NSF) is the federal steward for ground-based astronomy in the United States. Established in 1950, the NSF has helped shape American astronomy in the post-World War II period through a number of administrative decisions, including that of establishing national observatories from scratch. This paper will provide an overview of the support of astronomical research by the NSF during its first 25 years, highlighting key administrative decisions and awards.

91.05 – **Development of Infrared Astronomy**

George Rieke[1]

[1]*Univ. of Arizona.*

5:35 PM - 6:00 PM

We are only two years from celebrating the hundredth anniversary of William Coblentz's first extensive measurements of stars in the infrared. However, his work was followed for fifty years by ---- almost nothing. I will describe the few initiatives in those fifty years and compare them with the dramatic beginning of modern infrared astronomy in the 1960s. I will also quantify the explosive progress of this area since then. The comparison allows us to speculate on the real prerequisites for successful breakthroughs in astronomy and astronomical technology.

100 – Welcoming Address

Invited Session – Ballroom D – Monday, January 9, 2012, 8:00 AM - 8:30 AM

101 – Kavli Lecture: The CMB and Neutrinos

Invited Session – Ballroom D – Monday, January 9, 2012, 8:30 AM - 9:20 AM

100.01 – **The CMB and Neutrinos**

Lyman Page[1]

[1]*Princeton.*

8:30 AM - 9:20 AM

Massive neutrinos affect the temperature and polarization power spectra of the cosmic microwave background (CMB). The generation of CMB measurements now underway has the sensitivity to constrain the sum of neutrino masses to the 0.05 to 0.1 eV level assuming that they are the dominant massive relativistic particles in the early universe. Measurements of the atmospheric neutrino oscillations indicate that at least one neutrino species has a mass above 0.06 eV. Thus, in the context of the LCDM model of cosmology, we should be able to determine the neutrino mass sum through the neutrino's participation in cosmic evolution. After a brief overview of the LCDM model, we present results from current measurements of the CMB and then indicate the path toward constraining the neutrino mass with an emphasis on lensing the CMB.

140 – HEAD: New Results in High Energy Astrophysics

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

140.01 – **Spitzer Observations Of Mfl6 And The Associated ULX**

Ciprian T. Berghea[1], R. P. Dudik[1]

[1]*USNO.*
9:00 AM - 6:30 PM

We present Spitzer Infrared Spectrograph (IRS) observations of the Ultra-luminous X-ray source (ULX) in NGC 6946 and its associated nebula MF16. This ULX has very similar properties to the famous Holmberg II ULX. Like Holmberg II, the mid-IR ratios of the [O IV] to lower ionization lines are similar to those observed in AGN, suggesting that a strong UV and X-ray source is responsible for the photoionization. The best Chandra data is used to model the X-ray band and this data is then extrapolated into the UV. We use previously published UV and optical observations to construct the SED for the ULX and its companion. We use CLOUDY photoionization modeling to discriminate between the different ULX models and the observed IR line ratios. The simulations are consistent with a rather thin shell of ionized gas that is also seen in the optical and UV images. Our results suggest that the emission from the accretion disk only dominates the far UV and the X-ray emission. The optical companion is likely responsible for most of the near UV emission, and is consistent with an O supergiant. The irradiated accretion disk can also contribute significantly to the optical emission.

140.02 – **Characterization of the Breakdown of Magnetospheric Polarization Models**

Helen A. Craig[1], R. W. Romani[1]

[1]*Stanford University.*
9:00 AM - 6:30 PM

Radio emission from pulsars contain valuable information about geometry of the pulsar. In particular, polarization angle curves can be related to geometry via the popular rotating vector model. A modification to the rotating vector model proposed by Blaskiewicz, Cordes, and Wasserman (1991) allows for the additional measure of the emission height. At large heights, these analytic formulas break down. By comparing the analytic formulas to numerical simulations of emission we have performed probabilistic analysis to more precisely define this breakdown.

140.03 – **Chandra Survey Of Galactic Coronae Around Nearby Edge-on Disk Galaxies**

Jiang-Tao Li[1], D. Wang[1]

[1]*University of Massachusetts.*
9:00 AM - 6:30 PM

The X-ray emitting coronae in nearby galaxies are expected to be produced either by accretion from the IGM or by various galactic feedbacks. It is already well known that the total hot gas luminosity of these galaxies is correlated with the stellar mass for early-type galaxies and with SFR for star forming galaxies. However, such relations always have large scatter, indicating various other processes must be involved in regulating the coronal properties. In this work, we conduct a systematical analysis of the Chandra data of 53 nearby edge-on disk galaxies. The data are reduced in a uniform manner. Various coronal properties, such as the luminosity, temperature, emission measure, electron number density, total mass, thermal energy, radiative cooling timescale, vertical and horizontal extension, elongation, and steepness of the vertical distribution, are characterized for most of the sample galaxies. For some galaxies with high enough counting statistics, we also study the thermal and chemical states of the coronal gas. We then compare these hot gas properties to other galactic properties to further study the role of different processes in producing and/or maintaining the coronae. The soft X-ray luminosity of the coronae generally correlates well with the SF activity for our sample galaxies over more than 3 orders of magnitude in SFR or Lx. In addition, the inclusion of other galactic properties could significantly improve the correlation of the SFR-Lx relation. The SN feedback efficiency is at most 10% for all the sample galaxies. We also find evidence for the effectiveness of old stellar feedback, gravitation, environmental effects, and cold-hot gas interaction in regulating the coronal properties.

140.04 – **Modeling the Broadband Spectral Energy Distributions of Nearby Seyfert-1 AGN**

Dipankar Maitra[1], J. Miller[1], S. Markoff[2], A. King[1]

[1]*Univ. of Michigan,* [2]*Univ. of Amsterdam, Netherlands.*
9:00 AM - 6:30 PM

From available literature we are assembling high-quality, high-resolution broadband spectral energy distribution data of the nuclear region of nearby Seyfert-1 AGN. These SEDs span from radio through X-rays, and will be used to test whether the broadband SEDs can be explained within the framework of a relativistically outflowing jet model. In a recent work we have shown that once the contribution from the host galaxy is taken into account, the broadband emission from the active galactic nucleus of NGC 4051 can be well described by the jet model. In the framework of the jet model, the correlated high variability of the extreme ultraviolet and X-rays compared to other wavelengths suggests that the emission at these wavelengths is optically thin synchrotron originating in the particle acceleration site(s) in the jet very close (few rg) to the central supermassive black hole. Our conclusions support the hypothesis that narrow line Seyfert 1 galaxies (which NGC 4051 is a member of) harbor a "jetted" outflow with properties similar to what has already been seen in low-luminosity AGNs and stellar mass black holes in hard X-ray state. I will also discuss the recent progress in modeling broadband SEDs of some of the other nearby Seyfert-1 AGN.

140.05 – **NuSTAR's Role in Constraining Black Hole Spin in AGN**

Laura Brenneman[1], G. Matt[2], A. Fabian[3], K. Nandra[4], M. Elvis[1], M. Cappi[5]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Università degli Studi Roma Tre, Italy,* [3]*IoA Cambridge, United Kingdom,* [4]*MPE Garching, Germany,* [5]*INAF/IASF Bologna, Italy.*
9:00 AM - 6:30 PM

The angular momentum of a supermassive black hole (SMBH) can have profound effects on the inflow and outflow of matter and energy from the active galactic nucleus (AGN) in which it resides, consequently influencing the evolution of its host galaxy on larger scales as well. The science of measuring black hole spin is in its infancy, however; only within the last decade has the combination of fully relativistic models and space-based X-ray detectors with both high effective area and spectral resolution enabled the first robust estimates of black hole spin in SMBHs. Though spin measurements have been published for eight bright, nearby AGN, there is debate in the community about the accuracy of these constraints. At the core of this debate is the uncertainty involved in modeling the X-ray continuum, including the complex absorption intrinsic to many AGN. Broad band, high resolution X-ray spectra are needed to break the degeneracy between differing models and isolate the signatures of inner disk reflection that are the foundation of black hole spin measurements. The launch of NuSTAR in February 2012 will allow the hard X-ray emission from 5-80 keV to be observed with unprecedented spectral resolution and signal-to-noise (s/n). Simultaneous NuSTAR/XMM-Newton and/or NuSTAR/Suzaku observations of bright AGN will provide the broad band, high s/n spectra necessary to break the degeneracy between different continuum models, thereby enabling the most precise, accurate constraints on black hole spin ever achieved for these sources.

140.06 – **Current Status and Future Prospects for the Fermi Large Area Telescope**

Robert A. Cameron[1], W. B. Atwood[2], L. Baldini[3], E. Charles[4], L. S. Rochester[4], T. L. Usher[4], Fermi LAT Collaboration

[1]*KIPAC, SLAC, Stanford Univ.,* [2]*UC Santa Cruz,* [3]*INFN, University of Pisa, Italy,* [4]*SLAC National Accelerator Laboratory.*
9:00 AM - 6:30 PM

The Large Area Telescope (LAT) on the Fermi Gamma-ray Space Telescope (Fermi) is now in its fourth year of operation on orbit. The LAT is performing well after more than 200 billion triggered readouts of the instrument detector elements, with only very minor issues with its Silicon Tracker, CsI Calorimeter and Anti-coincidence detector sub-systems. We summarize the current operational status of the LAT. We also discuss some possible future improvements in LAT performance and capabilities, in measures such as low-energy response and angular resolution, which could be achieved through reconfiguration of trigger and readout systems in the detector, with pointers to some of the science gains expected from these possible instrument changes.

140.07 – **The Extreme Physics Explorer**

Michael R. Garcia[1], M. Elvis[1], J. Bookbinder[1], R. Smith[1], D. Patnaude[1], E. Bulbul[1], S. Bandler[2], A. Ptak[2], T. Okajima[2], T. Turner[3], G. Risalati[4], M. Galeazzi[5], E. Figueroa-Feliciano[6], D. Chakrabarty[7], R. Danner[8], D. Daily[8], G. Fraser[9], R. Willingale[10]

[1]*Harvard-Smithsonian, CfA,* [2]*NASA/GSFC,* [3]*UMBC,* [4]*Arcetri, Italy,* [5]*Univ of Miami,* [6]*MIT Kavli Institute,* [7]*MIT Department of Physics,* [8]*NGAS,* [9]*University of Leicester, United Kingdom,* [10]*University of Leicester.*
9:00 AM - 6:30 PM

The Extreme Physics Explorer (EPE) is a mission concept which has been submitted to the recent NASA RFI for 'Concepts for the Next NASA X-ray Astronomy Mission'.

It utilizes a high TRL foil optic mirror with 1 arcmin PSF and direct heritage to Astro-H, and a micro-calorimeter which can deliver 2eV spectral resolution and 80% throughput at several Crab fluxes, and remains photon limited down to fluxes of ~$2e^{-14}$ ergs/cm^2/s. The effective area for the foil mirror is >20x ASTRO-H, and a low-TRL micro-channel plate option could provide ~200x the ASTRO-H effective area. EPE can address a significant fraction of the IXO science as outlined in the RFI, at a cost well within the medium category as defined by the RFI. While ASTRO-H will give us the first taste of the 'integral field' spectroscopy possible with a micro-calorimeter, EPE will provide us with the first statistically significant samples within many classes of objects.

We will discuss both the science reach and the technologies of EPE in this poster.

140.08 – **Physical Model for the Revised Blazar Sequence**

Justin Finke[1], C. Dermer[1]

[1]*US Naval Research Laboratory.*
9:00 AM - 6:30 PM

The blazar sequence is reflected in a plot of the peak luminosity versus peak frequency of the synchrotron component of blazars. This diagram has been considered one of the fundamental pieces of evidence for the existence of a continuous sequence that includes low-power BL Lacertae objects through high-power flat spectrum radio quasars. Recently, Meyer et al. have shown that this plot displays an "L" or "V" shape that was not apparent in earlier representations of the blazar sequence. We find that this shape can be reproduced by a simple model where the external radiation field increases with increasing injection power of jet electrons. This leads to greater cooling of the electrons, which moves the synchrotron peak to lower frequencies. For more powerful injection, the electron cooling Lorentz factor becomes less than the minimum injected electron Lorentz factor, causing the peak frequency to become nearly independent of the jet power. The difference in viewing angles of different blazars can explain the scatter in the sequence.

140.09 – **Prospects for Observing Star-forming Galaxies with Future X-ray Missions**

Andrew Ptak[1]

[1]*NASA/GSFC.*

9:00 AM - 6:30 PM

We will discuss the prospects for observing star-forming galaxies with future X-ray satellites. In the near term, NuStar will enable hard X-ray observations of galaxies, including isolating hard X-ray emission from Ultraluminous X-ray Sources (ULXs) in nearby galaxies. Astro-H will allow the abundances and dynamics of hot gas in nearby galaxies to be studied via calorimeter spectral observations. Mission concepts such as AXSIO, EPE and Sahara will have the combined power of high spectral resolution, effective area and spatial resolution to dramatically increase the sensitivity of normal galaxy observations, including mapping hot disk and halo gas and detailed investigations of bright X-ray binaries. Finally, the survey missions eRosita and the Wide Field X-ray Telescope would detect on the order of 10^4 and 10^5 star-forming galaxies, respectively. Simulations for these missions will be presented based on current observations of nearby galaxies and implications for evolution from the Chandra Deep Fields. This work was supported in part by NASA Grants NNG04GE13G and SP89004X.

141 – Dark Skies, Technology and Archaeoastronomy

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

141.01 – **Nejat Aerospace Magnoplane**

Cyrus Nejat[1]

[1]*University of Southern California.*

9:00 AM - 6:30 PM

The Nejat Aerospace Magnoplane (NAM) is designed as a low speed (Mach < 1:00) aerial vehicle that it can be modified as a high speed aerial vehicle. This aerial vehicle is able to operate on highlands and hilly sites such as landing on and launching from the mentioned sites. The problem concerns with launching and landing of the vehicle on and from sites where there are highlands with bushes difficulties. Also, where there is short area for landing of regular airplane. This project is pursued for patent registration and highly modified version current airplanes.

141.02 – **Ancient Astronomy: A Study of the Point Remove Mound Complex**

Matt Hankins[1], D. L. Burris[1]

[1]*University of Central Arkansas.*

9:00 AM - 6:30 PM

Artificial solstice markers are a common thread across many early civilizations. With the beginnings of early agriculture, the need to be able to predict the changes in season became an issue of utmost importance. Many Native American groups used artificial mounds to mark different astronomical events. Toltec Mounds (located southeast of Little Rock, AR) is a complex set of structures left behind by the area's native people that is known to have alignments with the summer and winter solstice as well as an equinox alignment. The Point Remove mound complex (located outside Morrilton, Arkansas, also known as site 3CN4) is a known archeological site that has not been well studied, therefore has never been checked for any form of astronomical alignment. The purpose of this project is to study the Point Remove Mound site and look for features of astronomical significance. Study of Toltec Mounds will serve as a baseline for comparison. Study of the site consists of aerial photographs, topographic maps, and GPS measurements. In addition to studying alignments within the site, the location of the mound complex will be studied with respect to other known complexes like Toltec Mounds and Spiro Mounds (Oklahoma).

141.03 – **Seeing Stars: A GLOBE at Night Campaign Update**

Constance E. Walker[1], S. M. Pompea[2], R. T. Sparks[2], M. Newhouse[2]

[1]*NOAO,* [2]*NOAO, Tucson, AZ.*

9:00 AM - 6:30 PM

The emphasis in the international citizen-science, star-hunting campaign, GLOBE at Night, is in bringing awareness to the public on issues of light pollution. Light pollution threatens not only observatory sites and our "right to starlight", but can affect energy consumption, wildlife and health. GLOBE at Night has successfully reached a few 100,000 citizen-scientists. What has done in the last year to contribute to its success?

• To promote the campaign via popular social media, GLOBE at Night created Facebook and Twitter pages.

• Videos have been created for 4 out of 8 Dark Skies Rangers activities.

• Sky brightness measurements can be submitted in real time with smart phones or tablets using the new Web application at www.globeatnight.org/webapp/. The location, date and time register automatically.

• As a proto-type, an adopt-a-street program had people in Tucson take measurements every mile for the length of the street. Grid measurements canvassed the town, allowing for comparisons of light levels over time.

• The increase to 2 campaigns in 2011 re-enforces these studies. In 2012, the campaign will be offered 4 times for 10 days a month: January 14-23, February 12-21, March 13-22 and April 11-20.

• A new Web application (www.globeatnight.org/mapapp/) allows for mapping GLOBE at Night data points within a specified distance around a city or area of choice. The resulting maps are bookmarkable and shareable.

• NOAO and Arizona Game and Fish Department started a project with GLOBE at Night data and bat telemetry to examine a dark skies corridor in Tucson where endangered bats fly.

While providing these updates to the GLOBE at Night program, the presentation will highlight the education and outreach value of the program's resources and outcomes, lessons learned, successes and pitfalls in communicating awareness with the public and attracting young people to study science.

141.04 – **Light Pollution Around Tucson, AZ And Its Effect On The Spatial Distribution Of Lesser Long-nosed Bats**

Alisa Fersch[1], C. Walker[1]

[1]*National Optical Astronomy Observatory.*

9:00 AM - 6:30 PM

Light pollution is a well-known problem for astronomers. It is also gaining attention as an ecological issue. The federally endangered Lesser Long-Nosed Bat (Leptonycteris cursoae) resides for part of the year near Tucson, Arizona. It is possible that this species tends to avoid light. Excess artificial light would therefore interfere with the bats' flight patterns and foraging habits. In order to test this hypothesis, we quantified night sky brightness with data from the citizen-science campaign GLOBE at Night. Using direct measurements taken with a Sky Quality Meter (SQM), we created a contour map of the artificial night sky brightness around Tucson. When this map is compared to the approximate flight paths of the lesser long-nosed bat, we can see that the bats do appear to be avoiding the brightest area of Tucson. We also used logistic regression to analyze what combination of ecological variables (ecoregion, vegetation cover, landform and light) best describes the observed spatial distribution of lesser long-nosed bats. Of the models that were tested, light alone was not a good predictor of the bat presence or absence. However, light in addition to vegetation and ecoregion was the best model. This information can be useful for making decisions about lighting codes in areas of the city that the bats tend to traverse. The contour map of light pollution in Tucson will be useful for both future astronomy and ecology studies and can also be used for public outreach about light pollution.

Fersch 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 and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

142 – Gamma Ray Bursts

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

142.01 – **Dust Properties In Afterglow Of GRB 071025 At z~5**

Minsung Jang[1], M. Im[1], I. Lee[2], Y. Urata[2], K. Huang[3], H. Hirashita[3], X. Fan[4], L. Jiang[4]

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9:00 AM - 6:30 PM

Core-collapse supernovae (SNe) are suspected to be the dominant source of dust production at high redshift where AGB stars cannot contribute to dust formation. However, some observations indicate that the dust production by SNe is inefficient, which casts doubts on the existence of abundant SNe-dust in the early universe. Perley et al. (2010) previously reported that the afterglow of GRB 071025 - an unusually red GRB at z ~ 5 - shows evidence for the existence of SNe-dust. Although it might be the only high redshift GRB that exhibits compelling evidence for SNe-dust, the result could easily be changed by small systematics in photometry. Thus, we re-examined the extinction properties of GRB 071025 using our own optical/near-infrared data at a different epoch. In addition, we tested various SNe-dust models with different progenitor masses and dust destruction varying ambient gas density to constrain the dust formation mechanisms. By searching for the best-fit model of the spectral energy distribution of the afterglow, we confirm the previous claim that the dust in GRB 071025 is most likely to originate from SNe. We also find that the SNe-dust model of 13 or $25M_{sol}$ without dust destruction fits the extinction property of GRB 071025 best whereas pair-instability SNe (PISNe) models with a $170M_{sol}$ progenitor result in poor fits. Our results indicate that, at least in some systems at high redshift, the SNe with intermediate masses within 10 - $30M_{sol}$ were the main contributors of the dust enrichment, and the dust destruction effect due to reverse shock was negligible.

142.02 – **A Search for γ-Ray Burst Variability & Optical Afterglow Onset Correlations**

Sarah Yost[1], T. M. Moore[1]

[1]*St John's Univ.*.
9:00 AM - 6:30 PM

We compare the intrinsic gamma-ray variability (V) of γ-ray bursts (GRBs) to properties of their subsequent optical afterglow onset and find that a more comprehensive dataset than our previous work does not show statistically significant correlations between V and the onset time or peak shape. We fit 30 afterglow onset optical peaks, including the early rising lightcurve of GRB 080804; the fits yielded peak times as well as rise times, fall times and widths. We also used constraints from 47 early (t < 1 ksec) optical detections where the lightcurve was already in decline. A generalized Spearman rank test shows no significant evidence for correlation of V with the peak time, width, rise, decay, or ratio of rise to decay times, both for times de-redshifted or referenced to the GRB duration. As the optical onset time is an indicator of the external shock's Lorentz factor Γ, this result implies that there is no particular correlation between the diverse outcomes of the prompt γ-ray emission processes and the initial Γ.

142.03 – **GRB Flare Detection in UVOT Light Curves Using Bayesian Hidden Markov Models**

Craig A. Swenson[1], P. W. A. Roming[2]

[1]*The Pennsylvania State University,* [2]*Southwest Research Institute.*
9:00 AM - 6:30 PM

One of the great discoveries of the Swift era is that of continued GRB central engine activity beyond the prompt emission phase. The most convincing evidence of this late time activity is the presence of X-ray flares in nearly half of all Swift/XRT afterglow light curves. These flares can not be explained by external shocks and are thought to be the result of continued central engine activity. Similar flares have also been seen by the Swift/UVOT in the uv/optical bandpass, but generally at a much lower significance level. The understanding of these lower significance flares and determining whether they have the same physical origin as the larger X-ray flares is crucial to furthering our understanding of GRB physics and energetics. As a first step in this further understanding, we have analyzed all the UVOT light curves of GRBs detected between January 2005 and December 2010 with a Bayesian Hidden Markov Model and present our findings on the number of flares, as well as their general properties.

142.04 – **Photometric Analysis of the PAIRITEL Infrared Observations of Early Time Gamma Ray Burst Afterglows**

Pierre Christian[1], A. N. Morgan[1], J. S. Bloom[1], C. R. Klein[1]

[1]*UC Berkeley.*
9:00 AM - 6:30 PM

Since continuous operations began in 2004, the Peters Automated Infrared Imaging Telescope (PAIRITEL) has autonomously observed over 150 Swift GRBs within 24 hours of the trigger, including 16 in under 4 minutes of the trigger. Using improved pipelines, we have systematically re-reduced and photometered all observed events under 30 minutes of the trigger (20 bursts), yielding a homogenous sample of early-time JHKs lightcurves. Of the 20 bursts in our sample, 15 events have full-color light curves. Of the remaining bursts, 2 events are detected in at least one band and upper limits of the afterglow magnitude were obtained for the remainder of the set. We present an analysis of the results, showing IR magnitude/color distributions at fixed observer rest frame times since the trigger.

142.05 – **Modest Obscured Star-Formation Rates Inferred from EVLA Observations of Dark GRB Host Galaxies**

Daniel A. Perley[1], R. A. Perley[2]

[1]*Caltech,* [2]*NRAO.*
9:00 AM - 6:30 PM

If a significant fraction of cosmic star formation occurs in submillimeter- and radio-luminous galaxies, and if gamma-ray bursts serve as an unbiased tracer of star formation, many GRBs should be hosted within these systems - but few radio host detections have been reported to date. We present host observations with the full-bandwidth EVLA of a sample of highly dust-obscured ("dark") GRBs previously found to have occurred within significantly dust-obscured galaxies. All systems are quite faint at radio wavelengths, and most are undetected even at the level of the EVLA's sensitivity (RMS ~5 microJy). The implied radio-derived star-formation rates are modest, usually comparable to what is inferred from the dust-corrected optical observations. These results suggest that most dark GRBs occur within dusty regions of relatively ordinary galaxies, and indicate that the most extreme systems rarely produce GRBs.

142.06 – **Computational Methods: A New Limit on Lorentz Invariance and Chromatic Dispersion Across the Universe from GRB 090510A**

Ryan Connolly[1], R. J. Nemiroff[1], J. Holmes[1]

[1]*Michigan Technological University.*
9:00 AM - 6:30 PM

High-energy photon data from the Fermi LAT provides an excellent source for constraining Lorentz invariance and limiting photon dispersion across the Universe. Photon groupings at the super-GeV level in Fermi gamma-ray bursts suggest upper limits on the time scales for dispersion over cosmological distances. A computational Monte Carlo approach allows us to find conservative limits on dispersion time scales at various levels of significance. By generating many random sets of "photons" with the same conditions as a chosen LAT data set, any number of small time scales can be tested and compared between the random bursts and the actual burst to observe the uniqueness of this burst within a desired tolerance or significance level. Similarly, applying a method of gap multiplication to both actual and Monte Carlo cases provides another quantitative evaluation of the overall bunching reminiscent of entropy. We have developed such algorithms using GRB 090510A as a focused case due to the presence of heavily bunched structure at energies above 1 GeV. Bunching time scales in GRB 090510A were calculated at a 3-sigma significance level with both numerical approaches and the resulting limits on dispersion and variance in photon travel speeds are the strongest to date. The application of such algorithms to many GRBs - above 1 GeV or otherwise - not only allows for a broader overview of photon dispersion time scales but also easily singles out unique cases with significant bunching at higher energies.

142.07 – **Data and Results: A New Limit on Lorentz Invariance and Chromatic Dispersion Across the Universe from GRB 090510A**

Justin Holmes[1], R. J. Nemiroff[1], R. Connolly[1]

[1]*Michigan Technological University.*
9:00 AM - 6:30 PM

Statistical bunching of super-GeV photons from Fermi gamma ray burst 090510A is used to derive a new strict upper limit on the energy dependence of speed and dispersion of light across the universe. Photons over 1 GeV from four GRBs are selected within an energy dependent 2σ solid angle from the GRB center. In particular, bunched photons in 090510A have a significantly low Δ t which indicates variability below 0.00136 seconds. This extremely short Δ t is supported by statistical comparison using a modified correlation function of bunched photons with the natural time scale of photon arrival times throughout the burst. Δ E is observed in one photon pair to be close to 23.5 GeV. These parameters combined with a known redshift of *z* >/~ 0.897 were used to compute a limiting dispersion relation for Lorentz-invariance-violating effects.

This new limit of $\Delta c / c < 6.09 \times 10^{-21}$ is consistent, but stronger than the previous limits set by Schaeffer in 1999 for a different GRB. Specific limits in the cases of Δ t \propto Δ E and Δ t \propto Δ E^2 were computed using the most conservative values for parameters at their 2σ limits. These relations correspond to dispersion which may be due to dark energy, dark matter, or the foaminess of spacetime predicted by quantum gravity. In the specific case of quantum gravity, limits on photon dispersion of this type are calculated to be $M_1 c^2 > 7.43 \times \$10^{21}$ GeV and $M_2 c^2 > 7.13 \times 10^{11}$ GeV. These results are the most stringent limits yet claimed by several orders of magnitude, primarily supported by a strong Δ t.

143 – Cosmology & the CMB

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

143.01 – **A HIGH GRAVITATIONAL REDSHIFT?**

Gerardo A. Vazquez[1]

[1]*Salisbury University.*

9:00 AM - 6:30 PM

Theories in physics and astrophysics are based on several assumptions and concepts, but the most important concept is the one that transfers all the knowledge we have about the universe: light. This study, which is based on the most remarkable physical laws and astrophysical observations achieved in the last century, was conducted in order to review how constant the speed of light is in space. In this theory the variability of the speed of light depends upon gravity from point to point in the Universe, with the value we know being the initial speed of light, and the value changing as the photons move across the Universe. As long as the photons do not interact, they keep the information from the place they are coming from, but once they interact with anything their wave properties remove the memory of speed before their interaction with matter. This study finds that the gravity that permeates the local universe has a value of $\boldsymbol{g_u} = 9.72 \times 10^{-8}$ cms^{-2}. One of the important results of this study is the confirmation of dark matter and the prediction of a new substructure of the universe instead of a place close to the Big Bang.

143.02 – **Backgrounds and the High Redshift Universe**

Elizabeth R. Fernandez[1], I. Iliev[2], E. Komatsu[3], H. Dole[1], P. Shapiro[4]

[1]*Institut D'Astrophysique Spatiale, France,* [2]*Astronomy Centre, University of Sussex, United Kingdom,* [3]*Texas Cosmology Center,* [4]*University of Texas at Austin.*

9:00 AM - 6:30 PM

There are many ways to observe the high redshift universe. One of these is to study backgrounds, from the near infrared to the radio. These backgrounds can give information about the properties of star formation from intermediate redshifts (z~2-4) to high redshifts (z>6). One of the benefits of observing backgrounds is that they trace the star formation that is occurring in the majority of galaxies, not just those bright enough to be seen in high redshift galaxy surveys. I will discuss our recent theoretical work, as well as our analysis and interpretation of observations from the Herschel Space Telescope. Our results includes analysis of the mean intensity, fluctuations, and fractional anisotropy of the backgrounds. This gives information to constrain the epoch of reionization, including the mass of halos responsible for reionization, the escape fraction, and the star formation rate. Furthermore, I will talk about our attempts to resolve the background in the far infrared, and the strength of these observations, including our tests to assess the stability of stacking analysis. Lastly, I will discuss the prospects of future observations.

143.03 – **Correlation Between the Effective Neutrino Number and Curvature**

Aaron Smith[1], M. Archidiacono[2], A. Cooray[3], F. De Bernardis[3], A. Melchiorri[4], J. Smidt[3]

[1]*Brigham Young University,* [2]*Universita' di Roma "La Sapienza", Italy,* [3]*University of California Irvine,* [4]*Universita' di Roma "La Sapienza".*

9:00 AM - 6:30 PM

Cosmological data seems to favor models with more than three neutrinos. This poster focuses on recent discussion regarding additional sterile neutrinos and neutrino mass constraints in cosmology. We present a theoretical argument for correlation between the number of effective neutrinos and the curvature of the universe. This naturally arises from simple considerations of distance measurements. For example, with the degree of damping prior to recombination fixed by observation, we find that if we allow for an open universe then the angular diameter distance increases. To counterbalance this effect the sound horizon distance must increase as well which corresponds to decreasing the effective neutrino number. This qualitative argument is confirmed by statistical analysis with CosmoMC adapted to include CMB anisotropy measurements from a variety of experiments. This research was supported by Asantha Cooray at the University of California, Irvine.

143.04 – **The Ccd Camera Testing Instrument For The Bigboss Fiber Positioner**

Zengxiang Zhou[1], M. Sholl[2], C. Bebek[1]

[1]*Lawrence Brekeley National Lab,* [2]*Space Sciences Lab of UC Berkeley.*

9:00 AM - 6:30 PM

Throughput of a fiber-robot-based multi-object spectrograph depends on the accuracy and precision of the fiber position system. An efficient and accurate method of quantifying the performance of an actuator is necessary during the design iteration process, final design, and for post-production characterization. A CCD camera-based optical setup was developed at the Lawrence Berkeley National Laboratory to test these parameters of fiber robot positioners. The setup is described, as well as tests used to quantify distortion and cross-check measurement accuracy. Accuracy of the measurement was found to be better than three microns rms for lateral position error measurements.

143.05 – **On The CMB Disturbances From The Epoch Of Reionization**

Kayla Jaye Redmond[1], V. Strelnitski[2]

[1]*University of North Carolina-Asheville & Maria Mitchell Obs.,* [2]*Maria Mitchell Obs..*

9:00 AM - 6:30 PM

The possibility of observable spectral disturbances in the Cosmic Microwave Background (CMB) due to non-LTE effects in hydrogen recombination lines (in particular, maser amplification) produced during the epoch of reionization is re-visited. Such effects have been discovered in galactic HII regions and thoroughly studied theoretically. During the epoch of reionization, similar effects can, in principle, arise in large HII regions surrounding the first massive stars, star clusters and quasars. However, the theory developed for contemporary HII regions is not directly applicable to the HII regions of the reionization epoch because there is a considerably stronger (black-body) radiation background that tends to thermalize hydrogen transitions with high principal quantum numbers. We discuss the limitations due to radiative thermalization for possible non-LTE effects, as well as the anticipated frequencies and angular sizes of possible disturbances in the CMB. This project was supported by NSF/REU grant AST-0851892 and the Nantucket Maria Mitchell Association.

143.06 – **Inhomogeneous Universe Models: the Szekeres Model**

Robert Buckley[1], E. M. Schlegel[1]

[1]*University of Texas at San Antonio.*

9:00 AM - 6:30 PM

Observations of the luminosity distance and redshift of type Ia supernovae lead to the conclusion that the expansion of the universe is accelerating, but only when the observations are interpreted under the assumptions of homogeneity and isotropy on large scales. It has been shown that relaxing these assumptions allows for alternative universe models which match the observed distance-redshift relation without any mysterious ``dark energy''.

The simplest such models, the spherically symmetric Lemaître-Tolman-Bondi (LTB) class of models, have been much studied, and have been found by many to be problematic. The Szekeres class of models is a generalization of LTB which possesses no symmetries in general. It is able to better represent the lumpiness of the universe's matter distribution, and so it should serve as a more complete and accurate framework in which to interpret our observations.

We present an overview of the Szekeres model as it applies to cosmology. We show how its shape gives it advantages over LTB, such as a potential for faster structure formation, better compliance with the Copernican principle, and possibly even explaining the anomalous alignment of several cosmological observations. We briefly mention our progress on studying the CMB dipole seen by observers within a Szekeres universe.

This research was supported by the Texas Space Grant Consortium.

143.07 – **Growth of Structure in the Szekeres Inhomogeneous Cosmological Models**

Austin Peel[1], M. Ishak[1]

[1]*University of Texas at Dallas.*

9:00 AM - 6:30 PM

We investigate the effect of incorporating inhomogeneities into cosmological models. We focus on the growth of large-scale structure in the class II Szekeres models to see how it compares to that of the linearly perturbed Friedmann-Lemaître-Roberston-Walker (FLRW) solution. The Szekeres models are exact solutions to the Einstein field equations with no symmetries and an irrotational dust source. We use the formulation introduced by Goode and Wainwright, who considered the solutions as exact non-linear perturbations around a smooth FLRW background. In this form, the solutions are therefore well-suited for studying the growth of large-scale structure. Using the Raychaudhuri equation, we derive an exact equation for the growth rate that exhibits a linear part identical to the perturbed FLRW result plus additional non-linear terms. We integrate the equation numerically and examine the growth behavior in flat and curved universes that include a cosmological constant. We find that a flat Szekeres model with fractional density parameters equal to the accepted Lambda-Cold Dark Matter (ΛCDM) values experiences significantly stronger growth than its ΛCDM counterpart. Further, we are finding that a Szekeres model with only 4% baryonic matter and a cosmological constant can mimic the growth history of ΛCDM and remain consistent with observations. This work is supported in part by a grant from NASA.

143.08 – **How to Measure the Global Redshifted 21cm Signal**

Adrian Liu[1], J. R. Pritchard[2], A. Loeb[3], M. Tegmark[1]

[1]*Massachusetts Institute of Technology,* [2]*Imperial College London, United Kingdom,* [3]*Center for Astrophysics.*
9:00 AM - 6:30 PM

Making measurements of the highly-redshifted 21cm hyperfine transition of hydrogen is a potentially powerful way to constrain the Epoch of Reionization and the preceding Dark Ages. While experiments have traditionally focused on tomographic measurements, recently there has been a growing interest in measuring the global, angularly-averaged signal. Instruments used for the latter purpose have traditionally lacked angular resolution, and consist of (for instance) a single dipole. The lack of angular resolution can make foreground subtraction difficult, and we show that with better angular resolution, one can obtain global 21cm spectra with much smaller error bars. We also show that by incorporating some knowledge about the rough shape of the expected spectra, one can greatly increase the statistical significance with which cosmological signatures can be detected.

143.09 – **Constraining Cosmological Parameters, Including Neutrino Mass, Using N-body Large Scale Simulations and Artificial Neural Networks**

Shankar Agarwal[1], F. B. Abdalla[2], H. A. Feldman[1], O. Lahav[2], S. A. Thomas[2]
[1]*University of Kansas,* [2]*University College London, United Kingdom.*
9:00 AM - 6:30 PM

Future or ongoing galaxy redshift surveys such as BOSS and EUCLID will explore the nature of dark energy using the expansion history of our Universe and clustering information of large-scale structure. These surveys promise to achieve high-precision measurements of galaxy power spectrum amplitudes to 1%-level precision and offer a possibility to improve constraints on cosmological parameters, including neutrino masses. The standard linear theory of structure formation can not be used to make theoretical predictions on scales smaller than ~100 Mpc/h, below which the non-linear effects become significant compared to the precision of future surveys. One approach is to analytically model non-linear matter power spectrum based on higher-order perturbation theory. However, at redshift z=0, the perturbation approach is expected to reproduce the N-Body results within 1% - only for modes with $k < 0.1$ h/Mpc. The other approach to evaluate the small scale clustering is to run N-Body simulations over a finely spaced grid in multi (of order ~10) dimensional parameter space. If each parameter is sampled 10-20 times over its range, it would require a total of $10^{(10-20)}$ simulations. This is not feasible with each simulation consuming ~1000-2000 cpu hours.

Using Artificial Neural Networks (ANN) to model the non-linear matter power spectrum, we show that an optimally trained ANN is capable of reproducing the matter power spectrum obtained directly from N-body simulations, to within 1% precision upto $k < 1.0$ h/Mpc. Our preliminary analysis has shown that training an ANN requires a suite of at least 200 high-resolution N-Body simulations, which is far more feasible than $10^{(10-20)}$ simulations. We are currently running these simulations, using the ENZO code developed by the Laboratory for Computational Astrophysics at the University of California in San Diego (http://lca.ucsd.edu). This work is supported by the National Science Foundation through TeraGrid resources provided by the NCSA.

143.10 – **New High-Redshift Supernovae Ia for the Union Compilation of Type Ia Supernovae**

David Rubin[1], G. Aldering[2], R. Amanullah[3], K. Barbary[2], A. Bruce[1], K. Dawson[4], M. Doi[5], H. Fakhouri[1], A. Fruchter[6], A. Goobar[3], E. Hsiao[7], X. Huang[2], Y. Ihara[5], A. Kim[2], M. Kowalski[8], E. Krechmer[1], C. Lidman[9], E. Linder[2], J. Meyers[1], T. Morokuma[10], J. Nordin[2], S. Perlmutter[2], P. Ripoche[2], E. Rykoff[2], C. Saunders[1], T. Spadafora[2], N. Suzuki[2], N. Takanashi[10], N. Yasuda[5], Supernova Cosmology Project
[1]*UC Berkeley,* [2]*Lawrence Berkeley National Laboratory,* [3]*Stockholm University, Sweden,* [4]*University of Utah,* [5]*University of Tokyo, Japan,* [6]*Space Telescope Science Institute,* [7]*Carnegie Observatories, Chile,* [8]*Humboldt Univerity, Germany,* [9]*Australian Astronomical Observatory, Australia,* [10]*National Astronomical Observatory of Japan, Japan.*
9:00 AM - 6:30 PM

Building on the work presented in Amanullah et al. (ApJ, 2010) and Suzuki et al. (ApJ accepted), and adding new supernovae discovered in ground-based work, we present an updated dataset of $z \gtrsim 1$ supernovae. We update the SCP Union compilation with this data and present updated cosmological fits.

This work has been supported by the Office of Science, U.S. Department of Energy (through contract DE-AC02-05CH11231), and in part by NASA through grants associated with HST-GO-10496.

143.11 – **Correlations between Type Ia SNe and Host Galaxy Spectra**

Joshua Meyers[1], G. Graves[2], G. Aldering[2], K. Barbary[2], H. Fakhouri[1], J. Hennawi[3], E. Hsiao[4], S. Perlmutter[2], D. Rubin[1], E. Rykoff[2], C. Saunders[1], A. Spadafora[2], N. Suzuki[2]
[1]*University of California Berkeley,* [2]*Lawrence Berkeley National Laboratory,* [3]*Max-Planck-Institut fur Astronomie, Germany,* [4]*Carnegie Observatories.*
9:00 AM - 6:30 PM

We have obtained deep, very high signal-to-noise ratio spectra of a sample of ~40 host galaxies of Type Ia supernovae (SNe). The host galaxies are chosen from the Nearby SN Factory, the SDSS SN Survey, and Swift-observed SNe, with the requirement that they have early-type morphologies and passive stellar populations. We perform a detailed stellar population analysis of the SN host galaxies, measuring their ages and the abundances of multiple elements, including C, N, Mg, Ca, and Fe. We find that the abundance patterns of the SN hosts are similar to those of a control sample of early-type SDSS galaxies. However, a significant fraction, ~30%, show substantially younger mean stellar population ages, implying that ~30% of early-type hosted SNe Ia are associated with recent star formation. Additionally, we attempt to pinpoint the physics underlying the host mass -- SN Ia Hubble residual relation by investigating correlations between the host galaxy spectral properties and SN light curve properties.

143.12 – **Measuring the Mass Dependent Bias of the Spatial Correlation Function Using the C4 Cluster Catalog**

Brian Matthew Devour[1], C. J. Miller[1], D. Gifford[1], R. H. Wechsler[2], M. T. Busha[3], A. E. Evrard[1]
[1]*University of Michigan,* [2]*Stanford University,* [3]*University of Zürich, Switzerland.*
9:00 AM - 6:30 PM

We measure the bias of the cluster correlation function, and obtain its dependence on mass through the use of a new cluster mass estimator. Our data are based on analysis of ~2000 clusters within z=0.15 from the most recent version of the C4 cluster catalog - one of the largest spectroscopic cluster catalogs available, with a highly complete and well-understood selection function. We explore two different methods for measuring the covariance and errors of our correlation functions - the Jackknife and Bootstrap methods - and compare the predictions from these methods for a mock catalog with known bias. We then measure the bias by comparing the correlation function for sub-samples of our catalog against an unbiased theoretical correlation function derived from a large suite of simulations. By measuring the bias in multiple luminosity bins, we relate the bias to luminosity as a mass proxy and then measure the average mass of the clusters in each bin by stacking the caustic surfaces. This allows us to present the correlation function bias as a function of mass, which will improve our ability to link observation and theory in the formation of structure.

143.13 – **The Impact of Peculiar Velocity and Reionization Patchiness on 21cm Cosmology from the Epoch of Reionization**

Yi Mao[1], P. R. Shapiro[1], I. T. Iliev[2], G. Mellema[3], K. Ahn[4], K. Datta[3]
[1]*University of Texas at Austin,* [2]*University of Sussex, United Kingdom,* [3]*Stockholm University, Sweden,* [4]*Chosun University, Korea, Republic of.*
9:00 AM - 6:30 PM

Neutral hydrogen atoms in the intergalactic medium at high redshift contribute a diffuse background of redshifted 21cm radiation which encodes information about the physical conditions in the early universe at z>6 during and before the epoch of reionization (EOR). Tomography of this 21cm background has emerged as a promising cosmological probe. The assumption that cosmological information in the 21cm signal can be separated from astrophysical information (i.e. that fluctuations in the total matter density can be measured separately from the dependence on patchy reionization and spin temperature) is based on linear perturbation theory and the anisotropy introduced by peculiar velocity. While it is true that fluctuations in the matter density at such high redshift are likely to be of linear amplitude on the large scales which correspond to the beam- and bandwidths of upcoming experiments, the nonlinearity of smaller scale structure in density, velocity and reionization patchiness can leave its imprint on the signal, which might then spoil the linear separation scheme. We have built a robust and efficient computational scheme to predict the 21cm background in observer redshift space, given real-space simulation data, which accounts for peculiar velocity in every detail. We apply this to the results of new state-of-the-art large-scale reionization simulations which combine large-box, high-resolution N-body simulations of the LCDM universe (with up to 165 billion particles in comoving boxes up to 607 Mpc on a side in present units) with radiative transfer simulations of reionization, to test the validity of using 21cm background measurements for cosmology and characterize the predicted signal for upcoming radio surveys. This work was supported in part by NSF grants AST-0708176 and AST-1009799, NASA grants NNX07AH09G, NNG04G177G and NNX11AE09G, and Chandra grant SAO TM8-9009X.

143.14 – **The Effects of Primordial Non-Gaussianity on Cosmic Reionization**

Anson D'Aloisio[1], P. R. Shapiro[1], J. Zhang[1], Y. Mao[1], I. T. Iliev[2], G. Mellema[3], K. Ahn[4]
[1]*University of Texas at Austin,* [2]*University of Sussex, United Kingdom,* [3]*Stockholm University, Sweden,* [4]*Chosun University, Korea, Republic of.*
9:00 AM - 6:30 PM

Most studies of cosmic reionization are based upon the rise of structure in a cold dark matter dominated universe from Gaussian random initial density fluctuations, which are consistent with current constraints from the Cosmic Microwave Background and large-scale clustering of galaxies. However, some inflationary models predict a larger deviation from Gaussianity in the initial conditions, so there is great interest in the possibility of detecting or further constraining the amplitude and type of primordial non-Gaussianity (PNG). We model the effects of PNG on reionization by a variety of techniques, including linear perturbation theory, semi-analytic models based on the extended Press-Schechter formalism, and large-scale radiative transfer simulations coupled to cosmological N-body simulations of structure formation. We quantify the effects of PNG on the history and topology of reionization, and the signatures of PNG in future observations of the 21cm line during the epoch of reionization.

143.15 – **New Results on Cosmic Reionization**

Paul R. Shapiro[1], I. T. Iliev[2], G. Mellema[3], K. Ahn[4], Y. Mao[1], J. Koda[5], U. Pen[6]

[1]*The University of Texas at Austin,* [2]*University of Sussex, United Kingdom,* [3]*University of Stockholm, Sweden,* [4]*Chosun University, Korea, Republic of,* [5]*University of Swinburne, Australia,* [6]*CITA/University of Toronto, Canada.*

9:00 AM - 6:30 PM

When the first starts began to form in the LCDM universe at high redshift, they released ionizing and dissociating UV radiation into their surroundings which influenced the formation of other stars and galaxies, near and far, and left an observable imprint on the first billion years of cosmic evolution. The theory and simulation of this process depend upon combining elements of cosmological structure formation on scales large and small with radiative transfer, gas and gravitational dynamics. Results will be presented of our latest large-scale simulations of reionization and its observable signatures, including fluctuations in the cosmic 21cm, near-IR and microwave backgrounds. We have now simulated reionization using our C2RAY method to trace the ionizing and dissociating UV radiation from the millions of galactic halo sources, through the underlying intergalactic density field, computed with our CUBEP3M N-body code with as many as 165 billion particles, in comoving volumes that range from 30 to 600 Mpc on a side.

This work is supported by NSF, NASA, and the U.Texas TACC.

143.16 – **SPIDER: Probing the Early Universe with a Suborbital Polarimeter**

Aurélien A. Fraisse[1], SPIDER Collaboration

[1]*Princeton University.*

9:00 AM - 6:30 PM

SPIDER is a balloon-borne polarimeter designed to detect a divergence-free polarization pattern ("B-modes") in the Cosmic Microwave Background (CMB). In the inflationary scenario, the spectrum of the tensor perturbations that generate this signal is proportional to that of the primordial scalar perturbations through the tensor-to-scalar ratio r. The expected level of systematic error in the SPIDER instrument is significantly below the amplitude of an interesting cosmological B-mode signal with r=0.03. An optimized scanning strategy enables us to minimize uncertainty in the reconstruction of the Stokes parameters used to characterize the CMB, while providing access to a relatively wide range of angular scales. In the SPIDER field, the polarized emission from interstellar dust is as bright or brighter than the cosmological r=0.03 B-mode signal at all SPIDER frequencies (90, 150, and 280 GHz), a situation similar to that found in the "Southern Hole." Despite this foreground contamination, two 20-day flights of the SPIDER instrument will constrain the amplitude of the B-mode signal to r<0.03 (99% CL). In the absence of foregrounds, the same limit can be reached after one 20-day flight.

The Spider collaboration gratefully acknowledges the support of NASA (APRA-NNX07AL64G), the National Science Foundation (ANT-1043515), the Gordon and Betty Moore Foundation, and the David and Lucile Packard Foundation. Support in Canada is provided by NSERC, the Canadian Space Agency, the Canada Foundation for Innovation, and CIFAR.

143.17 – **Measurements of the Sunyaev-Zel'dovich Effect Increment with Herschel**

Michael B. Zemcov[1], Herschel Multi-tiered Extragalactic Survey (HerMES), Herschel Lensing Survey (HLS)

[1]*California Institute of Technology.*

9:00 AM - 6:30 PM

The Sunyaev--Zel'dovich (SZ) effect is a spectral distortion of the cosmic microwave background as observed through the hot plasma in galaxy clusters. This distortion is a decrement in the cosmic microwave background intensity for lambda > 1.3 mm, an increment at shorter wavelengths, and small again by lambda ~ 200 microns. The Spectral and Photometric Imaging Receiver (SPIRE) on the Herschel Space Observatory has bands centered at 250, 350 and 500 microns which ideally span the short wavelength end of the SZ effect increment. Measurements at these wavelengths confirm the spectral behaviour of the SZ effect, and are optimally positioned to constrain the temperature of the inter-cluster medium through relativistic corrections to the thermal SZ spectrum. The Herschel Multi-tiered Extragalactic Survey and Herschel Lensing Survey programmes have mapped tens of massive clusters with SPIRE and, among other science highlights, have detected the SZ effect at the two longest SPIRE wavelengths. In this paper we present new measurements of the SZ effect increment and constraints on the sub-mm contamination present in cluster fields for longer wavelength measurements of the SZ effect.

143.18 – **Comparing Cosmology Parameters: Dark Energy vs Cosmological Constant**

Jeramy Lewis[1], P. Timbie[2]

[1]*University of Colorado-Boulder,* [2]*University of Wisconsin-Madison.*

9:00 AM - 6:30 PM

The Cylindrical Radio Telescope (CRT) is designed to use the redshifted 21-cm line from HI to create a 3-D intensity map of the large scale structure of the universe. The goal is to measure the angular size of baryon acoustic oscillations (BAO) as a function of redshift. Using the angular diameter distance and redshifts the CRT can constrain the equation of state of the dark energy. In particular it can determine whether or not the dark energy is consistent with a cosmological constant. We plotted the distance-redshift relation for a variety of physically-motivated equations of state and compared them to a ΛCDM (concordance) model. The graphs indicate the accuracy with which the distances must be measured to constrain dark energy models. I thank the University of Wisconsin for allowing my participation in their astrophysics REU program and to the National Science Foundation and the U.S. Department of Defense through ASSURE for the funding through NSF Award AST-1004881.

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144 – The Sun

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

144.01 – **A Technique for Detecting Propagating Coronal Waves with the VLA**

Steven R. Spangler[1]

[1]*Univ. of Iowa.*

9:00 AM - 6:30 PM

There is currently great interest in measuring outward-propagating waves and disturbances in the solar corona. These waves and disturbances are naturally interpreted as the Alfvén waves which heat the corona and drive the solar wind. An ideal way of measuring these waves is via Faraday rotation measurements with the Very Large Array (VLA) of an extended radio source viewed through the corona. In principle, the same rotation measure time series should be observed for each polarized component in the source, but lagged by the propagation time across the source. The difficulty with this type of measurement is that VLA maps must be made with a fast cadence, i.e. 10 - 30 seconds, to resolve the expected propagation time across a typical source with an angular extent of 40 - 60 arcseconds. Such a short integration time results in noisy maps and nearly precludes measurements of the polarization position angle χ. In this paper, I discuss an alternative technique for measuring coronal rotation measure time series for two or more components of an extended radio source, using the directly measured intensities of the Stokes parameters Q and U. The technique was applied to VLA observations of the radio galaxy 3C228 during the coronal occultation of August 2003. Although the signal-to-noise environment in this case was not sufficient to measure propagating disturbances, the exercise does show that the algorithm and data processing method work. The data also show weak evidence for rotation measure fluctuations on time scales of a few minutes. Observations with the Expanded Very Large Array (EVLA) should permit a successful application of the technique. This research was supported at the University of Iowa by grant ATM-0956901 from the National Science Foundation.

144.02 – **Ultraviolet Emissions and Magnetic Field Changes during Solar Flares**

Brittany Johnstone[1], G. Petrie[2], J. Sudol[1]

[1]*West Chester University,* [2]*National Solar Observatory.*

9:00 AM - 6:30 PM

We compare ultraviolet emissions from the chromosphere, obtained from Transition Region and Coronal Explorer (TRACE) images, and longitudinal magnetic field changes in the photosphere, obtained from Global Oscillation Network Group (GONG) magnetograms, during five X-class solar flares. An abrupt, significant, and persistent change in the magnetic field occurred across more than ten pixels in the GONG magnetograms during each flare. In all cases, ultraviolet emissions occur along the same line of sight as the field changes. The ultraviolet emissions lag the GOES x-ray start times for the flares and lead the changes in the magnetic field with the longest time delay being no more than ~13 minutes. The ultraviolet emissions decay well after the field changes are complete. The observations are consistent with the picture in which an Alfven wave from the field reconnection site in the corona propagates outward in all directions, including downwards through the chromosphere and into the photosphere.

144.03 – **Detecting Flows, Waves and Nanoflares in the Solar Corona**

Brandon Calabro[1], J. McAteer[1], A. Pevtsov[1]

[1]*New Mexico State University.*
9:00 AM - 6:30 PM

Oscillations in the solar corona are studied using data from Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA). We use a wavelet analysis to search for oscillatory signals in 3D datacubes (two spatial dimensions, one temporal dimension) in each of the extreme ultraviolet passbands of AIA, and apply a pixel-grouping algorithm to enable us to study coherent patches of the solar corona. By looking at regions of the corona that oscillate at similar periodicity we are able to interpret the spatial behavior of oscillations through different heights in the solar corona and transversely across the corona. We propose a method to identify and extract flows, waves, and nanoflares and determine the contribution of each of these in heating coronal plasma.

144.04 – **Nonlinear Force-Free Modeling of Aug 4 & 10, 2010 Sigmoids via Flux Rope Insertion Method**

Tyler Behm[1], E. DeLuca[2], A. Savcheva[2]

[1]*Texas A&M University,* [2]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

The high spatial resolution of space-based solar telescopes like AIA and Hinode/XRT has allowed us to see fine S-shaped structures in active regions. The collection of such S-shaped loops is known as a sigmoid and are of great interest to solar physics since 68% of coronal mass ejections appear in such regions. In our research, we detail methods of studying sigmoids by using magnetograms to make non-linear force free field models and by comparing these models to the observed loops in X-ray and EUV images. We use the flux rope insertion method to set the initial parameters for these models. Furthermore, we examine the ability of contour maps of field divergence to study the field topology of sigmoids. From our models, we estimate the free energy stored in the sigmoids. From our field divergence maps, we find features of high divergence also known as quasi-separatrix layers, which can point to probable location for reconnection.

144.05 – **Coronal Loop Detection and Seismology**

Alexander Pevtsov[1], R. T. J. McAteer[1], J. Jackiewicz[1], B. McNamara[1], M. Kirk[1], K. Degrave[1], L. Boucheron[1], B. Calabro[1]

[1]*New Mexico State University.*
9:00 AM - 6:30 PM

We study the spatial distribution and temporal evolution of coronal loops using data from the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA). We apply an automated coronal loop detection algorithm that is maximized for accuracy and completeness, and reconnects orphaned segments of coronal loops, to extreme ultraviolet images of the solar corona. We quantify the loop size distribution with a scaling index in each of the SDO AIA passbands, and show how this changes with time. This provides new insights into the physical mechanisms that create coronal structure.

144.06 – **Asymmetric Magnetic Reconnection in Coronal Mass Ejection Current Sheets**

Crystal Pope[1], M. P. Miralles[2], N. A. Murphy[2]

[1]*Elmhurst College,* [2]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

Flux rope models of coronal mass ejections (CMEs) predict the formation ofan elongated current sheet in the wake behind the rising plasmoid. These current sheets have been seen to drift or tilt over time by instruments including SOHO/LASCO and Hinode/XRT. We measure this in multiple observations including the 2008 April 9 "Cartwheel CME" and find an average drift that is far more than can be accounted for via the effects of solar rotation. The observed drift could be due to different parts of the current sheet actively reconnecting at different times (e.g., Savage et al. 2010), macroscopic effects from the rising flux rope pulling the plasma sheet along with it, or asymmetry in the magnetic reconnection process itself. These drift rates are compared with resistive magnetohydrodynamic (MHD) simulations of line-tied reconnection between magnetic fields of different strengths. The observed drift rates are comparable to predictions made by the simulations.

144.07 – **Models and Comparisons of Long Duration and Impulsive Solar Flare Events from SDO**

Trevor Bowen[1], P. Testa[2], K. Reeves[2]

[1]*Marlboro College,* [2]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

We compare observational signatures of two GOES C8-class solar flares through instrumentation on Solar Dynamics Observatory (SDO). Data from the Atmospheric Imaging Assembly (AIA) and the Extreme Ultraviolet Variability Experiment (EVE) provide a unique look at the sun through global scale, fast cadence, high-resolution photometric and spectral measurements; this data is ideal for analyzing the temporal evolution of flare properties. The two flares studied differ in both time scale and morphology, one may be classified as a long duration event (LDE), while the other is highly impulsive. Differences are noted in behavior in the AIA EUV bands as well as several spectral lines. Furthermore, we apply both zero and one dimensional multi-threaded hydrodynamic loop models to synthesize light curves and spectra for each flare. Funding provided by NSF REU solar physics program at CfA, grant number ATM-0851866 and Marlboro College.

144.08 – **The Solar Oxygen Crisis, Revisited**

Thomas R. Ayres[1]

[1]*University of Colorado.*
9:00 AM - 6:30 PM

For years, controversy has raged over what seemingly should be a well-established property of our Sun, the solar oxygen abundance. Spectroscopic estimates early last decade based on advanced 3D time-dependent photospheric convection simulations, suggested that the true oxygen abundance was almost 40% lower than the value (680 ppm relative to hydrogen) recommended only a few years prior. The unexpectedly low value sparked what has come to be called the ``Solar Oxygen Crisis,'' because the previous higher abundance was almost exactly what was required by helioseismology to reproduce the interior sound speed profile, well-characterized from surface p-mode measurements. Although in most other parts of Astronomy, agreement to within a factor of two is cause for celebration, in this case -- despite intense efforts on both sides -- there did not seem to be an easy way to reconcile the disparate results from the inside and outside of the Sun. In this study, I examine the surface spectroscopy side of the issue, bringing to bear additional diagnostics, such as center-to-limb behavior, on the one hand to validate the thermal properties of the 3D convection models, and on the other to provide additional leverage on the abundance issue. The main conclusion is that existing 3D models can reproduce the key continuum center-limb effect in the visible, showing that the mean thermal gradient in the deep atmosphere is accurate, but the same models misunderestimate intensities in the inner wings of the H and K resonance lines of ionized calcium, a signature of too-low temperatures in the middle photosphere (where key oxygen bearing CO and OH reside). Implications for a unified description of the oxygen abundance from atomic and molecular species are discussed. This work supported by NSF.

144.09 – **SPIES: Spectropolarimetric Imager for Energetic Sun**

Andrew Weis[1], H. Lin[2]

[1]*University of Pittsburgh & Institute for Astronomy, University of Hawai'i,*

[2]*Institute for Astronomy, University of Hawai'i.*
9:00 AM - 6:30 PM

Solar magnetic fields are responsible for the appearance of the solar atmosphere. These magnetic fields are non-uniform, and are strongest over sunspots. Magnetic fields are thought to cause energetic phenomena such as solar flares and coronal mass ejections, which can have damaging consequences in the near-Earth space environment and high latitude regions, providing practical in addition to scientific reasons to study them. Current instrumentation for observations of solar magnetic fields use scanning slit spectrograph or tunable filter, which allow us to resolve the time evolution of the fields to the scale of minutes or longer. We are constructing a new instrument, SPIES, based on a large-format (32 x 64) fiber-optic integral field unit (IFU). The fiber-optic IFU allows us to observe over two spatial dimensions and one spectral dimension simultaneously rather than in steps, thus allowing for resolution of the time evolution to the level of seconds. Due to fiber modal noise and small thermal drift of the instrument over time, flat-fielding of the intensity spectra from the discrete fiber-optic 'slits' becomes time dependent. An observing scheme that records time-sensitive flat-fields was devised for SPIES. We will present preliminary analysis of the full-Stokes polarization spectra of a sunspot obtained with SPIES over a 90 minute time span. This work was conducted through a Research Experience for Undergraduates (REU) position at the University of Hawai'i's Institute for Astronomy and was funded by the NSF.

144.10 – **Observations of the Neupert Effect with the Solar Dynamics Observatory, Reuven Ramaty High Energy Solar Spectroscopic Imager, and Geostationary Operational Environmental Satellite**

Sam J. Schonfeld[1], P. C. Chamberlin[2]

[1]*Whitman College,* [2]*NASA GSFC.*
9:00 AM - 6:30 PM

The Neupert Effect is an empirically observed correlation between the hard X-rays (HXR) and the time derivative of soft X-rays (SXR) emitted during the impulsive phase of a solar flare. According to standard models of magnetic reconnection driven flares, accelerated electron beams are responsible for creating the HXR Bremsstrahlung radiation in the Transition Region and upper Chromosphere. This energy input should also heat the relatively low-temperature Chromospheric plasma, increasing the intensity of extreme ultraviolet (EUV) emission lines. The launch of the Extreme Ultraviolet Variability Experiment (EVE) on board the Solar Dynamics observatory (SDO) has for the first time provided measurements of the solar irradiance spectra with 0.1 nm spectral resolution over the range 6.5-37 nm at 10-second cadence and nearly 100%

duty cycle. Comparisons were made using the EUV spectral data from EVE, SXR measured by the X-Ray Spectrometer (XRS) on the Geostationary Operational Environmental Satellites (GOES), and HXR recorded with the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). The first focus of the investigation looked at the timing of the HXR, time derivative of soft X-ray, and the Helium-II 304Å doublet. The second focus compared He II images taken by the Atmospheric Imaging Assembly (AIA) (also on SDO) to x-ray images taken by RHESSI to compare the spatial location and area of the lower atmospheric energy emissions. We investigated all M class and above flares between May 1st 2010 and June 1st 2011 with complete coverage by all three instruments totaling 31 events. Of these, 77% (24) showed the expected Neupert Effect with 70% (17) of these events also displaying He-II profiles consistent with the electron beam heating model. This collaboration was organized through the SESI internship program at GSFC and funded by the Catholic University of America.

144.11 – **Intelligent Search of Solar Data**

Yifan Hao[1], H. Cao[1], B. McNamara[1], J. Jackiewicz[1], J. McAteer[1], L. Boucheron[1], D. Voelz[1], M. Kirk[1], G. Taylor[1], K. DeGrave[1], A. Al-Ghraibah[1], A. Pevtsov[1], B. Calabro[1]

[1]*New Mexico State University.*
9:00 AM - 6:30 PM

The enormous amount of solar data, a result of new observational missions, needs to be stored and retrieved intelligently. Existing systems (e.g., the Science Archive of the Solar and Heliospheric Observatory (SOHO); soho.nascom.nasa.go) manage solar data merely using metadata (e.g., the time that images were taken) or other programmatic information. As a result, such systems can only support very primitive queries (e.g., images taken in June 2009). From such search results, scientists have to manually select their needed data for further analysis.

On the other hand, solar data, either raw or processed, are often associated with semantic information such as the active regions in an image and corresponding text annotations. Such semantic knowledge can provide much more insights to the data and can help scientists quickly find data that are related to a specific research goal or topic (e.g., solar flares or coronal mass ejections). A solar data management system should be able to intelligently utilize such relevant semantic data to facilitate solar data retrieval, and ultimately saves investigators valuable time.

In this work, we build a prototype for the intelligent retrieval and exploration of solar data by utilizing the semantic knowledge associated with raw or processed solar data. The core of this prototype is a "query processing" component that utilizes a unified index technique to support both simple basic queries (e.g., images taken in 2007) over the metadata and intelligent topic queries (e.g., image regions related to "Solar Flares" in 2007) over other complicated contents. This component leverages different types of data (especially semantic information) to improve the search accuracy. Besides this, another facilitating component is designed to provide user-friendly result exploration functionalities when the "query processing" component returns a set of query results.

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145 – Computation, Data Handling, Image Analysis

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

145.01 – **Astrodrizzle: Advanced Camera for Surveys Mosaic of the Sombrero Galaxy M104**

Amber Armstrong[1], S. Gonzaga[1], A. Fruchter[1], W. Hack[1], M. Mutchler[1], R. Lucas[1]

[1]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

We present an example of a high-level science product created using AstroDrizzle, a new task that replaces MultiDrizzle. AstroDrizzle is one of several tasks in the new AstroDither package that replaces the Dither package. A mosaic of M104 (the Sombrero galaxy) was created from ACS WFC images of 24 overlapping fields at 6 pointings to form a combined image that reveals fine details of the galaxy's edge-on grandeur. In this example, we emphasize use of the tweakreg task, also in the AstroDither package, that provides a semi-automated interface for computing offsets between input images that will be combined using AstroDrizzle. Much of the same algorithmic base used in MultiDrizzle is maintained in AstroDrizzle. However, AstroDrizzle employs a fundamentally different approach to handling image distortions and astrometry based entirely on FITS WCS conventions that simplifies data analysis efforts (see Fruchter et al., AAS January 2012). It also provides slightly better cosmic ray rejection, and fixes several bugs in MultiDrizzle. For additional information about the AstroDither package, please refer to the 'AstroDrizzle Handbook,' available at http://www.stsci.edu/hst/HST_overview/documents.

145.02 – **PhAst: A Flexible IDL Astronomical Image Viewer**

Morgan Rehnberg[1], R. Crawford[2], M. Trueblood[3], K. Mighell[3]

[1]*Beloit College,* [2]*Rincon Ranch Observatory,* [3]*National Optical Astronomy Observatory.*
9:00 AM - 6:30 PM

We present near-Earth asteroid data analyzed with PhAst, a new IDL astronomical image viewer based on the existing application ATV. PhAst opens, displays, and analyzes an arbitrary number of FITS images. Analysis packages include image calibration, photometry, and astrometry (provided through an interface with SExtractor, SCAMP, and missFITS). PhAst has been designed to generate reports for Minor Planet Center reporting. PhAst is cross platform (Linux/Mac OSX/Windows for image viewing and Linux/Mac OSX for image analysis) and can be downloaded from the following website at NOAO: http://www.noao.edu/staff/mighell/phast/. Rehnberg 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 and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

145.03 – **High Speed White Dwarf Asteroseismology with the Herty Hall Cluster**

Aaron Gray[1], A. Kim[1]

[1]*Georgia College and State University.*
9:00 AM - 6:30 PM

Asteroseismology is the process of using observed oscillations of stars to infer their interior structure. In high speed asteroseismology, we complete that by quickly computing hundreds of thousands of models to match the observed period spectra. Each model on a single processor takes five to ten seconds to run. Therefore, we use a cluster of sixteen Dell Workstations with dual-core processors. The computers use the Ubuntu operating system and Apache Hadoop software to manage workloads.

145.04 – **The Lick Index Calibration of the Gemini Multi-Object Spectrographs**

Brett Basarab[1]

[1]*Middlebury College.*
9:00 AM - 6:30 PM

The Lick index system of standard stars is crucial for determining ages and metallicities of unresolved stellar populations. This project involves a calibration of the Gemini Multi-Object Spectrographs (GMOS) onto the Lick Standard index system. By comparing the well-defined spectral absorption features of the Lick stars to GMOS spectral absorption observations, we can accurately calibrate GMOS. Differences between these GMOS observations and Lick features, once determined, will result in correction factors that can be used for the calibration. This calibration of GMOS is useful because it allows for more accurate observations of unresolved stellar populations using the GMOS instrument. Although the observations and data reduction of the GMOS spectra was largely complete, we needed to insure the accuracy of the GMOS observations. We previously noticed unphysical errors in the shapes of some of the original GMOS spectra, so we carefully analyzed the data reduction process in order to find the source of these errors and ultimately correct them. The preliminary part of this process involved experimentation with various methods in order to narrow down the potential sources of the errors. Ultimately, we hypothesized that the unphysical errors may have been due to the presence of scattered light in the un-extracted spectra, which the original reduction program did not eliminate. We re-reduced some GMOS spectra, including the IRAF task apscatter in the reduction script to subtract the scattered light, and found that many unphysical errors were corrected. Deciding that the subtraction of the scattered light was effective, we re-reduced all GMOS Lick spectra, including the new apscatter step. The results were mixed, as the elimination of the scattered light corrected many of the poorly shaped spectra, but some errors remained. Further analysis of the spectral reduction process will hopefully determine the source of these remaining errors.

145.05 – **Improving Automatic Detection of Variable Stars**

Allyn Durbin[1], R. Siverd[2], J. Pepper[2], K. Stassun[2]

[1]*Villanova University,* [2]*Vanderbilt University.*
9:00 AM - 6:30 PM

The Minimum Entropy (ME) method described by Cincotta, et al. (1995) is a useful and efficient technique for identification of periodic signals in sparse time-series data. Its original form, however, struggles to correctly identify periods in the high-cadence time-series data with diurnal data gaps common to ground-based transit surveys. We developed a Modified Minimum Entropy (MME) technique to alleviate this problem and tested it with light curves from the KELT transit survey. We find that MME correctly recovers the periods of numerous variable types despite the uneven phase sampling of our test light curves. We further developed a related method to robustly remove outlier data points from phased variable light curves. Together, these techniques may improve

variable object yields from the vast data stores of modern high-cadence ground-based photometric surveys.

145.06 – **The Effect of Non-stationary Noise on Drifting Signal Detection**

Mauricio Flores[1], M. Benacquista[1], A. Stroeer[1]

[1]*University of Texas at Brownsville.*
9:00 AM - 6:30 PM

We analyze the effect of non-stationary noise in the detection of drifting signals on unevenly sampled data. Initial frequency estimation is obtained from a Lomb-Scargle periodogram; which is followed by a global multi-start optimization, as working on a dense local Nelder-Mead iterator for parameter estimates. It has been found that a varying white noise level has no effect on the required relative signal-to-noise ratio for detection in the proposed algorithm, though affecting the absolute amplitude strength of the signal recording. Future work includes the addition of colored noise to this analysis. We plan to investigate how this work can be applied to gravitational wave data analysis, for example LISA or LIGO. This work is funded by NASA URC Grant NASA NNX09AV06A, ARCC grant NSF AST0750913 and CREST grant NSF HRD0734800.

145.07 – **Comparison and Verification of RFI Excision Techniques**

Caroline Houston[1]

[1]*National Radio Astronomy Observatory.*
9:00 AM - 6:30 PM

The goal of RFI excision is to retain the sky signal of interest by subtracting out the interfering signal, rather than flagging it as unusable. In theory, matrix-decomposition techniques on the observed visibilities can be used to separate sky signal from ground RFI signal. Starting from first principles, the goal of this presentation is to illustrate how certain methods perform in ideal simulated situations, so that in the future one can complicate and build upon the methods presented here to predict how they would perform on real data. Tests were performed on simulated sky models made of bright and faint point and extended emission with terrestrial RFI that was either stationary or moving with respect to the telescope. Accuracy of the excision was determined by a statistical comparison of an ideal image with the result image and by the ability to determine the physical location of the RFI from the excised phase information. The results show that eigendecomposition and singular value decomposition of visibility matrices are capable of separating and subtracting out RFI signal in ideal situations.

145.08 – **Astrodrizzle: Optimally Combining Subsampled WFC3 & ACS Data**

Abhijith Rajan[1], J. Mack[1], H. Bushouse[1], M. Dulude[1], L. Petro[1], N. Pirzkal[1], W. F.C.3 team[1]

[1]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

AstroDrizzle is an improved STScI software tool for combining dithered HST images and removing geometric distortion. We present the results using AstroDrizzle to combine data taken from multiple detectors over several epochs, including WFC3 in both the UVIS and IR channels and early epoch ACS/WFC images. Using the spiral galaxy "NGC 3370" as an example, we will show improvements to the standard pipeline products that are achievable by optimizing the image combination when observations are obtained with sub-pixel dithering. We will compare these products with those created using the earlier generation software MultiDrizzle. As a part of our final product we will make the test data available, along with a cookbook detailing the process in a methodical manner, allowing users to reproduce the multi-channel optimally combined products using the new software.

145.09 – **Reduction and Analysis of GALFACTS Data in Search of Compact Variable Sources**

Trey Wenger[1], S. Barenfeld[2], T. Ghosh[3], C. Salter[3]

[1]*Boston University,* [2]*University of Rochester,* [3]*Arecibo Observatory.*
9:00 AM - 6:30 PM

The Galactic ALFA Continuum Transit Survey (GALFACTS) is an all-Arecibo sky, full-Stokes survey from 1225 to 1525 MHz using the multibeam Arecibo L-band Feed Array (ALFA). Using data from survey field N1, the first field covered by GALFACTS, we are searching for compact sources that vary in intensity and/or polarization. The multistep procedure for reducing the data includes radio frequency interference (RFI) removal, source detection, Gaussian fitting in multiple dimensions, polarization leakage calibration, and gain calibration. We have developed code to analyze and calculate the calibration parameters from the N1 calibration sources, and apply these to the data of the main run. For detected compact sources, our goal is to compare results from multiple passes over a source to search for rapid variability, as well as to compare our flux densities with those from the NRAO VLA Sky Survey (NVSS) to search for longer time-scale variations.

145.10 – **The Astrophysics Source Code Library: An Update**

Alice Allen[1], R. J. Nemiroff[2], L. Shamir[3], P. J. Teuben[4]

[1]*Calverton, MD,* [2]*Michigan Technological University,* [3]*Lawrence Technological University,* [4]*University of Maryland.*
9:00 AM - 6:30 PM

The Astrophysics Source Code Library (ASCL), founded in 1999, takes an active approach to sharing astrophysical source code. ASCL's editor seeks out both new and old peer-reviewed papers that describe methods or experiments that involve the development or use of source code, and adds entries for the found codes to the library. This approach ensures that source codes are added without requiring authors to actively submit them, resulting in a comprehensive listing that covers a significant number of the astrophysics source codes used in peer-reviewed studies. The ASCL moved to a new location in 2010, and has over 300 codes in it and continues to grow.

In 2011, the ASCL (http://asterisk.apod.com/viewforum.php?f=35) has on average added 19 new codes per month; we encourage scientists to submit their codes for inclusion.

An advisory committee has been established to provide input and guide the development and expansion of its new site, and a marketing plan has been developed and is being executed. All ASCL source codes have been used to generate results published in or submitted to a refereed journal and are freely available either via a download site or from an identified source.

This presentation covers the history of the ASCL and examines the current state and benefits of the ASCL, the means of and requirements for including codes, and outlines its future plans.

145.11 – **Astroinformatics, Cloud Computing, and New Science at the Canadian Astronomy Data Centre**

Nicholas M. Ball[1]

[1]*Herzberg Institute of Astrophysics, Canada.*
9:00 AM - 6:30 PM

With a collection of over 0.5 petabytes of information, and serving nearly 3000 astronomers worldwide, CADC is one of the world's largest astronomy data centres. Its unique blend of astronomers and computer specialists results in a rich interaction between world experts that is ideal for the fostering of developments within astroinformatics. CADC retains science drivers as the primary motivator at each step of the process, from the receipt of raw data from telescopes to its release and use by scientists. Developments are therefore guided by maximal benefit to the astronomy community.

The Canadian Advanced Network for Astronomical Research (CANFAR) is a University of Victoria and CADC project that builds on the existing CADC infrastructure to provide storage, processing, and analysis tools needed to enable astronomers to perform data-intensive astronomy on current and next generation datasets, using their existing codes. CANFAR provides a Virtual Cluster, accessed via a Virtual Machine environment, over which the user has complete control, and access to Cloud Computing on the Compute Canada Grid. Its services are compliant with the International Virtual Observatory Alliance standards. Hence, rather than build a new infrastructure for a project such as a sky survey, an individual or collaboration may utilize CANFAR.

CANFAR's main focus is on the storage and processing of data. By analogy to the argument that CANFAR can provide the generic hardware portions of a data processing pipeline, we implement fast, scalable, data mining algorithms that simplify the generic portions of knowledge discovery in databases within current and future datasets. This is a necessary step in further enabling practical data-intensive astronomy. We show an example of the use of the SkyTree software to perform K-means clustering to determine which galaxies in the Next Generation Virgo Cluster Survey (NGVS) are cluster members. This problem is unsolved within the survey.

145.12 – **DAta Mining and Exploration (DAME): New Tools for Knowledge Discovery in Astronomy**

Stanislav G. Djorgovski[1], G. Longo[2], M. Brescia[3], C. Donalek[1], S. Cavuoti[2], M. Paolillo[2], R. D'Abrusco[4], O. Laurino[4], A. Mahabal[1], M. Graham[1]

[1]Caltech, [2]Univ. Federico II, Napoli, Italy, [3]Osservatorio Astronomico di Capodimonte, Italy, [4]Harvard-Smithsonian Center for Astrophysics.

9:00 AM - 6:30 PM

The exponential growth of data volumes and complexity in astronomy, as in almost every other field of science, presents both great opportunities and great challenges for an effective knowledge discovery. We describe DAta Mining and Exploration (DAME), a general purpose, Web-based, distributed infrastructure for an effective data mining in massive and complex data sets. DAME includes machine-learning tools such as a variety of Artificial Neural Networks, Support Vector Machines, Self-Organizing Maps, Bayesian Networks, etc., for tasks such as an automated classification or regression fitting in multi-dimensional parameter spaces, etc. DAME also provides workspaces and grid access mechanisms, as well as an extensive documentation and user guides. We illustrate DAME applications on several scientific examples. DAME represents a new generation of astroinformatics tools that will become increasingly important for the data-rich astronomy in the 21st century.

145.13 – **Database Architecture for the Indra Cosmological Simulations**

Daniel S. Crankshaw[1], B. Falck[1], T. Budavari[1], L. Dobos[2], G. Lemson[3], M. Neyrinck[1], A. Szalay[1], J. Wang[4], R. Burns[1]

[1]Johns Hopkins University, [2]Eotvos Lorand University, Hungary, [3]Max-Planck Institute for Astrophysics, Germany, [4]University of Durham, United Kingdom.

9:00 AM - 6:30 PM

The Indra Simulation suite is a set of 512 cosmological N-body simulations in a 1Gpc/h-sided box producing over 100 TB of data. We present the data storage strategy developed to efficiently answer the most important questions being asked of this data. Some of these queries involve sampling all of the particle data for a particular snapshot, such as computation of particle topologies like filaments, voids, and clusters. The other queries involve searching a snapshot for information about a few particles, such as tracking halo member particle positions through time. We present a SQL database design to support the dataset by allowing efficient storage and querying. The particle data consists of positions and velocities for each particle, identified by a unique ID throughout the instance, as well as FOF halos and the density field on a power of two grid. In each timestep, the particle data is sorted along a Peano-Hilbert curve, and all particles within a single cell are placed into a single binary array stored in one row in the database using a custom SQL array library. To still allow for fast querying on these arrays, we associate a Bloom filter with each array to test whether a given particle is contained within it. A Bloom filter is a space efficient data structure to test set membership in constant time. Example query code and performance tests will be given.

The authors are grateful for support from the Gordon and Betty Moore and the W.M. Keck Foundations.

145.14 – **Constructing Concept Schemes From Astronomical Telegrams Via Natural Language Clustering**

Matthew Graham[1], M. Zhang[1], S. G. Djorgovski[1], C. Donalek[1], A. J. Drake[1], A. Mahabal[1]

[1]Caltech.

9:00 AM - 6:30 PM

The rapidly emerging field of time domain astronomy is one of the most exciting and vibrant new research frontiers, ranging in scientific scope from studies of the Solar System to extreme relativistic astrophysics and cosmology. It is being enabled by a new generation of large synoptic digital sky surveys - LSST, PanStarrs, CRTS - that cover large areas of sky repeatedly, looking for transient objects and phenomena. One of the biggest challenges facing these is the automated classification of transient events, a process that needs machine-processible astronomical knowledge. Semantic technologies enable the formal representation of concepts and relations within a particular domain.

ATELs (http://www.astronomerstelegram.org) are a commonly-used means for reporting and commenting upon new astronomical observations of transient sources (supernovae, stellar outbursts, blazar flares, etc). However, they are loose and unstructured and employ scientific natural language for description: this makes automated processing of them - a necessity within the next decade with petascale data rates - a challenge. Nevertheless they represent a potentially rich corpus of information that could lead to new and valuable insights into transient phenomena.

This project lies in the cutting-edge field of astrosemantics, a branch of astroinformatics, which applies semantic technologies to astronomy. The ATELs have been used to develop an appropriate concept scheme - a representation of the information they contain - for transient astronomy using hierarchical clustering of processed natural language. This allows us to automatically organize ATELs based on the vocabulary used. We conclude that we can use simple algorithms to process and extract meaning from astronomical textual data.

145.15 – **AstroDither: Drizzling with Astrometry Included**

Andrew S. Fruchter[1], W. Hack[1], N. Dencheva[1], M. Droettboem[1], P. Greenfield[1], C. Sontag[1]

[1]STScI.

9:00 AM - 6:30 PM

We present a new package of programs for aligning and drizzling HST images. AstroDither works on the principle that all astrometric and distortion information should be included in the calibrated image. Large external astrometric calibration files are no longer required. If the user wishes, multiple astrometric solutions can be contained in one header, and full astrometric solutions, including all distortion information, can be passed to other users or back as small FIITS files which we call headerlets. This approach greatly simplifies aligning images to each other or to external catalogs, and has allowed us to replace MultiDrizzle with a new program, AstroDrizzle, that handles absolute astrometry more naturally and with greater accuracy.

145.16 – **Automated Classification of Flaring Behavior in Solar Active Regions: Preliminary Results**

Amani Al-Ghraibah[1], L. E. Boucheron[1], R. McAteer[1], H. Cao[1], J. Jackiewicz[1], B. McNamara[1], D. Voelz[1], B. Calabro[1], K. DeGrave[1], Y. Hao[1], M. Kirk[1], A. Pevtsov[1], J. Mckeever[1], G. Taylor[1]

[1]New Mexico State University.

9:00 AM - 6:30 PM

Solar active events are the source of many energetic and geo-effective events such as solar flares and coronal mass ejections (CMEs). Understanding how these complex source regions evolve and produce these events is of fundamental importance, not only to solar physics but also the demands of space weather forecasting. In this poster, we present preliminary results from our analysis of the physical properties of active region magnetic fields using fractal-, gradient-, neutral line-, emerging flux-, and wavelet-based techniques. These analyses look to use the defined physical measures to form a predictive model for flaring behavior in active regions.

145.17 – **A Modern Astrophysical MHD Solver on CUDA-Capable GPUs**

Ben Ryan[1]

[1]University of North Carolina at Chapel Hill.

9:00 AM - 6:30 PM

Current numerical simulations employed by the astrophysics simulation community typically require long times to complete, particularly for three-dimensional regions. The recently developed CUDA extensions for C allow existing code to be modified to run on modern graphics cards in an efficient and parallelizeable manner. Graphics cards, particularly those developed for scientific computation, have significant speed advantages over CPUs for highly-parallelizeable applications such as magnetohydrodynamics grid solvers. Athena, a grid-based MHD code for astrophysics (Stone et al. 2008), is retooled to run on CUDA capability 2.0 or greater NVIDIA

graphics cards, with effort taken to maximize performance. Performance benchmarks between graphics cards and CPUs are presented.

145.18 – **Pass 8: A Comprehensive Revision Of The Fermi Lat Event-level Analysis**

William Atwood[1]

[1]*UCSC.*

9:00 AM - 6:30 PM

The event simulation and reconstruction framework developed for the Fermi Large Area Telescope before the launch performed beyond our expectations and proved to be adequate for the science of the first two years. This framework has been regularly updated to reflect the constantly improving knowledge of the detector and the environment in which it operates.

In parallel, a coherent long-term effort is ongoing, aimed at a radical revision of the entire event-level analysis based on the experience gained in the first phase of the mission. The basic ingredients of the new event simulation and reconstruction are in place and ready to serve as input into the new background rejection chain, which is now being developed.

Pass8 will come close to realizing the full scientific potential of the LAT. The expected improvements include (but are not limited to) greatly reducing the backgrounds, increasing the effective area, arriving at a better understanding of the systematic uncertainties and extending the energy reach of the photon analysis below 100 MeV and above 100 GeV.

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146 – Relativistic Astrophysics, Gravitational Lenses & Waves

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

146.01 – **The Orphan Lenses Project**

Leonidas A. Moustakas[1], J. Brownstein[2], R. Fadely[3], C. D. Fassnacht[4], R. Gavazzi[5], T. Goodsall[1], R. L. Griffith[6], C. R. Keeton[7], J. P. Kneib[8], A. Koekemoer[9], L. V. E. Koopmans[10], P. J. Marshall[11], J. Merten[1], R. B. Metcalf[12], M. Oguri[13], C. Papovich[14], H. Rein[15], R. Ryan[4], K. R. Stewart[1], T. Treu[16]

[1]*JPL/Caltech,* [2]*Univ. of Utah,* [3]*Haverford College,* [4]*UC Davis,* [5]*IAP, France,* [6]*IPAC/Caltech,* [7]*Rutgers,* [8]*LAM, France,* [9]*STScI,* [10]*Kapteyn, Netherlands,* [11]*Oxford, United Kingdom,* [12]*Univ. of Bologna, Italy,* [13]*IPMU, Japan,* [14]*TAMU,* [15]*IAS,* [16]*UCSB.*

9:00 AM - 6:30 PM

Strong gravitational lenses are uniquely suited for the study of dark matter structure and substructure within massive halos of many scales, act as gravitational telescopes for distant faint objects, and can give powerful and competitive cosmological constraints. Some 300 lenses have been identified in the literature in one form or another; many others have been found, but perhaps have not warranted dedicated publications. The Orphan Lenses project aims to be a master compilation of all strong gravitational lenses that are known, and a community repository for candidate lenses. A clear and uniform database of basic properties and gravitational lens models is being developed, which will be available online and through a smartphone interactive application. I will present the project, and scientific highlights with this dataset.

146.02 – **CANDELS: Properties of Strong Lensing Galaxy UDS-01**

Jae Alyson B. Calanog[1], H. Fu[1], A. Cooray[1], A. Chiu[1], J. Wardlow[1], CANDELS team

[1]*University of California, Irvine.*

9:00 AM - 6:30 PM

UDS-01 was one of the strong lensing candidates selected for further analysis from the Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS) Hubble Space Telescope (HST) / Widefield Camera-3 (WFC3) images. With HST/WFC3's 0.2 arcsecond resolution, these new images reveal new information about this system that poor resolution ground based telescopes would be missing. It is a bonafide gravitational lens and features two background sources at two different redshift values previously identified by ground based imaging in the Canada-France-Hawaii Telescope Legacy Survey (CFHTLS). This poster presents updated results for the lens model utilizing the latest data and reports values for the lensing total mass and the stellar mass of a source at z = 1.84.

146.03 – **Microlensing Analysis of the Gravitationally Lensed Quasar SDSS 1650+4251**

Garrett Deletti[1], C. W. Morgan[1], L. J. Hainline[1], H. C. Harris[2]

[1]*US Naval Academy,* [2]*US Naval Observatory, Flagstaff Station.*

9:00 AM - 6:30 PM

We present and analyze variability in the optical photometry from our monitoring campaign of the doubly-imaged lensed quasar SDSS1650+4251. We use point spread-function modeling to separate the flux from each of the system's two images in 4 seasons of optical monitoring data from the US Naval Observatory, Flagstaff Station. We analyze these light curves using a Monte Carlo microlensing analysis technique, attempting to reproduce the observed lightcurves with a reasonable set of physical variables. We compile the Monte Carlo results using a Bayesian maximum likelihood technique to yield estimates of the average stellar mass in the lens galaxy, the lens galaxy's dark matter fraction and the quasar's accretion disk size at optical wavelengths.

146.04 – **Microlensing Analysis Of Quasars Sbs 0909+532 And Sbs 1520+530**

Zachary Landaal[1], C. Morgan[1], L. Hainline[1], H. Harris[2]

[1]*US Naval Academy,* [2]*US Naval Observatory Flagstaff.*

9:00 AM - 6:30 PM

We have used the gravitational microlensing variability observed in the gravitationally lensed quasars SBS 0909+532 and SBS 1520+530 to measure the physical size of their continuum sources at optical and X-ray wavelengths using optical monitoring data from the United States Naval Observatory (USNO) in Flagstaff, Arizona and one epoch of X-ray imagery from the Chandrasekhar X-Ray Observatory archive. We have used a point-spread function modeling technique to measure the flux of the blended quasar components to yield a set of time-sequenced lightcurves, plots of the brightness of each image with respect to time. Using the lens astrometry and photometry measured from publicly available Hubble Space Telescope data, I have calculated models for the mass distribution in the lensing galaxy. The models have been used to generate magnification patterns for representative star fields in the lens galaxy. After generating the magnification patterns, I employed a Bayesian Monte Carlo microlensing analysis technique to simultaneously analyze the X- ray and optical observational data.

146.05 – **The Environmental Dependence of Dynamical and Lensing Mass Differences**

Matthew Thomas Nichols[1], R. Nichol[2], G. Zhao[2], R. Crittenden[2], J. T. Lauroesch[1]

[1]*University of Louisville,* [2]*Institute of Cosmology and Gravitation, University of Portsmouth, United Kingdom.*

9:00 AM - 6:30 PM

Recent work in modified gravity suggests there should be observable, environmentally dependent differences between the lensing and dynamical masses of elliptical galaxies. Using a sample of previously identified lensing galaxies at redshifts between 0.1 and 0.3 from SDSS DR8, we define a density of neighboring galaxies using SDSS photometric redshifts for volumes of differing radii. We then compare the differences between dynamical and lensing masses with environment and compare to the numerical simulations.

146.06 – **Observing SNe Ia Progenitors with LISA**

Frank Ceballos[1], A. Stroeer[1], M. Benacquista[1], K. Belczynski[2]

[1]*The University of Texas at Brownsville,* [2]*University of Warsaw, Poland.*

9:00 AM - 6:30 PM

The Galactic population of close white dwarf binaries is expected to provide the largest number of gravitational wave sources for low frequency detectors such as the Laser Interferometer Space Antenna (LISA). Current data analysis techniques have demonstrated the capability of resolving on the order of 10^4 white dwarf binaries from a 2 year observation. Resolved binaries are either at high frequencies or large amplitudes or both. Such systems are more likely to be high-mass binaries, a subset of which will be progenitors of Type Ia supernovae in the double degenerate scenario. We report on the results of a study of the properties of resolved binaries using a population synthesis model of the Galactic white dwarf binaries and a LISA data analysis algorithm using Mock LISA Data Challenge tools.

146.07 – **Prospects For Detection Of Extragalactic Stellar Mass Black Hole Binaries With Space-based Gravitational-wave Observatories**

Jesus Hinojosa[1], A. Mata[1], M. Benacquista[1], A. Stroeer[1]

[1]*ARCC UTB.*

9:00 AM - 6:30 PM

Stellar mass black hole binaries are systems with individual masses of 10-80 solar masses. These systems may be detectable with space-based gravitational wave observatories at megaparsec distances. We investigate the selection effects for the observation of these systems for detectors similar to the Laser Interferometer Space Antenna. Using a uniform distribution in parameters describing the masses, periods, orientation, sky location and distance, we apply a signal-to-noise threshold cut to determine the characteristics of potentially observable systems in order to determine the

biases of an observed sample relative to the model population.

146.08 – **The International Pulsar Timing Array Workbench, A Web-based Application.**

Jose Martinez[1], F. A. Jenet[1], J. D. Romano[1], K. Lee[2], R. Shannon[3], L. S. Finn[4], D. Perrodin[5]

[1]*University of Texas at Brownsville,* [2]*Max Planck Institute for Radio Astronomy, Germany,* [3]*CSIRO Astronomy and Space Science, Australia,* [4]*Pennsylvania State University,* [5]*Franklin & Marshall College.*

9:00 AM - 6:30 PM

There is currently an international effort to detect gravitational waves using radio pulsar timing techniques. The detection will involve the analysis of signals observed from a large number of radio pulsars by many different observatories. We have developed an on-line web tool known as the International Pulsar Timing Array workBENCH (IPTA-BENCH) that will allow researchers to determine the effectiveness of different observing strategies for the detection of gravitational wave

signals. This poster describes the current and future capabilities of IPTA-BENCH.

146.09 – **Background Sky Variability for Multi-messenger Follow-up Surveys**

Katelyn Breivik[1], S. L. Larson[1]

[1]*Utah State University.*

9:00 AM - 6:30 PM

Future gravitational wave detections by both ground and space based laser interferometric observatories will possibly have electromagnetic counterparts on the sky. Detecting these counterparts will provide important complementary information, allowing a more complete characterization of the astrophysical source. The pointing provided by gravitational wave observatories will be quite broad compared to the normal field of view of a typical telescope, necessitating the development of sophisticated search strategies to identify electromagnetic counterparts. An important aspect of search strategies is knowing how much confusion on the sky will result from other objects that are varying in brightness during the follow-up survey. This project seeks to characterize the background sky variability on small regions of the sky as a function of galactic latitude for sub-meter class telescopes.

146.10 – **Parameter Estimation for Black Hole Mergers with Aligned Spin**

Tyson Littenberg[1], J. Baker[2], A. Buonanno[3], R. Lang[4], S. T. McWilliams[5]

[1]*University of Maryland College Park / NASA Goddard Spaceflight Center,* [2]*NASA Goddard Spaceflight Center,* [3]*University of Maryland College Park,* [4]*Washington University,* [5]*Princeton University.*

9:00 AM - 6:30 PM

Mergers of black holes are among the cornerstone sources for gravitational wave (GW) detectors. Optimal analysis of these signals relies on coherent matched-filtering which, in turn, demands accurate analytic waveforms. These templates must be efficiently computed for arbitrary parameters, precluding the use of Numerical Relativity simulations in a data analysis context. The Effective One Body (EOB) approach allows for relatively rapid construction of full waveforms which are calibrated against Numerical Relativity simulations. We will study the measurement capabilities of gravitational wave detectors using EOB waveforms as templates, building on previous studies by including

the black hole spins as parameters in the model. Due to limitations of the waveform model, this study is restricted to black hole binaries with spin-angular momentum vectors aligned with the orbital angular momentum. Nevertheless, it is an important stepping stone towards understanding the full reach of gravitational wave astronomy.

146.11 – **Testing Gravitational Physics with Space-based Gravitational-wave Observations.**

John G. Baker[1], J. Gair[2], S. Larson[3], M. Vallisneri[4]

[1]*NASA/GSFC,* [2]*Cambridge, United Kingdom,* [3]*Utah State University,* [4]*Jet Propulsion Laboratory.*

9:00 AM - 6:30 PM

Gravitational wave observations provide exceptional and unique opportunities for precision tests of gravitational physics, as predicted by general relativity (GR). Space-based gravitational wave measurements, with high signal-to-noise ratios and large numbers of observed events may provide the best-suited gravitational-wave observations for testing GR with unprecedented precision. These observations will be especially useful in testing the properties of gravitational waves and strong-field aspects of the theory which are less relevant in other observations. We review the proposed GR test based on observations of massive black hole mergers, extreme mass ratio insprials, and galactic binary systems.

146.12 – **Hardware Verification of Time Delay Interferometry with Space-craft Motion Effects for Space-based Gravitational Wave Interferometers.**

Shawn Mitryk[1], G. Mueller[1]

[1]*University of Florida.*

9:00 AM - 6:30 PM

The detection of gravitational waves (GWs) with the use of future space-based interferometer missions, such as the Next Gravitational Wave Observatory (NGO), will require advanced interferometry schemes in order to account for unequal arm-lengths and space-craft motion effects. These complications are resolved using measurements of one-way laser observables and post-processing combinations which cancel the laser noise and extract the differential arm-length, collectively, referred to as Time Delay Interferometry (TDI). The University of Florida (UF) has constructed a hardware-in-the-loop experiment, know as the UF Laser Interferometry Simulator (UFLIS), to replicate the pre-stabilized laser noise, multi-second light travel time delays, GW laser-phase modulation, and the formation and measurement of photodetector laser beatnotes using a microcycle phasemeter as is expected in these space-based interferometers. The measurements are then combined using the TDI combinations to verify the interferometer sensitivity after laser noise cancellation.

146.13 – **Overlap Reduction Functions for Pulsar Timing Arrays in Alternative Theories of Gravity**

Sydney Chamberlin[1], X. Siemens[1]

[1]*University of Wisconsin-Milwaukee.*

9:00 AM - 6:30 PM

In the next decade gravitational waves could be detected using a pulsar timing array. In an effort to develop optimal detection strategies for stochastic backgrounds of gravitational waves in generic metric theories of gravity, we investigate the overlap reduction functions for these theories and discuss their features. We show that sensitivity increases for non-transverse gravitational waves and discuss the physical origin of this effect. We calculate the overlap reduction functions for the current NANOGrav Pulsar Timing Array (PTA) and show that the sensitivity to the vector and longitudinal modes can increase dramatically for pulsar pairs with small angular separations. For example, the J1853-J1857 pulsar pair, with an angular separation of ~3 degrees, is about 10^4 times more sensitive to the longitudinal component of the stochastic background, if it's present, than the transverse components.

This project was completed in part with funding from the Wisconsin Space Grant Consortium and the NSF through CAREER award number 09955929 and PIRE award number 0968126.

146.14 – **The Population Of Multi-messenger Ultra-compact Galactic Binaries**

Shane L. Larson[1], T. B. Littenberg[2]

[1]*Utah State University,* [2]*Goddard Spaceflight Center.*

9:00 AM - 6:30 PM

Space-based gravitational wave interferometers are strongly sensitive to the galactic population of ultra-compact binaries. An important subset of the ultra-compact binary population are those stars that can be individually resolved by gravitational wave interferometers as well as with electromagnetic telescopes. The aim of this paper is to quantify the multi-messenger potential of space-based interferometers with arm-lengths between 1 and 5 Gm. First we examine the known ultra-compact binaries that have been well-studied with electromagnetic telescopes. Using the known astrophysical properties of the verification binaries as priors for a Markov Chain Monte Carlo study, we show that our ability to further constrain the individual masses of the system or the distance to the source is not greatly affected by changes in the size of the detector. Second, the Fisher Information Matrix is used to estimate how many binaries from a synthesized model of the Milky Way below a certain magnitude limit are localized on the sky to within 1 square degree by the gravitational wave detector. This is taken as an estimate of how many prospective candidates a space-based interferometer will discover that could then be studied with electromagnetic telescopes. We find, depending on choice of detector characteristics and limiting magnitude, that tens to thousands of gravitational wave sources could be detected in electromagnetic follow-ups.

146.15 – **High Precision Pulsar Timing: Effects of ISM Correction Schemes**

Willie Kunert[1], J. P. W. Verbiest[2], R. Shannon[3], D. Stinebring[1]

[1]*Oberlin College,* [2]*Max Planck Institute of Radio Astronomy, Germany,* [3]*Australia Telescope National Facility, Australia.*

9:00 AM - 6:30 PM

Pulsar timing arrays are one of the leading methods in the search for gravitational waves (GWs). However a significant issue facing this method is the effect of the interstellar medium (ISM). There are multiple methodologies being used to correct for these effects but their efficacy has not been carefully studied. We conducted an initial study of biases induced by correcting for the interstellar medium. We simulated times of arrival (TOAs) with white noise and added ISM delays. We measure the ISM effects as is done with normal data, and created a model of these effects using polynomial fitting. This modeling method is most commonly used in the European Pulsar Timing Array. We then remove these measured ISM effects and compare final and initial TOAs. Ideally they should be the same; however, the differences between the 'corrected' TOAs and original TOAs

reveal the weaknesses of this method. In preliminary results we concluded that the higher order polynomials do a better job, yet there is a limit as to how high an order one can use. We also found no significant systematic parameter bias induced by using this method. However, it is clear that certain parameters are more affected by this process of correction. The parameters most affected were the frequency and frequency derivative of the pulsar, but biases in these parameters are not important because the power due to them gets removed in the standard timing analysis. We are continuing this research by comparing and contrasting ISM correction schemes, as well as studying the actual behavior of the ISM in more detail. This research is supported by an NSF-PIRE and an NSF-AST grant.

146.16 – **NANOGrav High-Precision Millisecond Pulsar Timing and Gravitational Wave Background Limit**

David J. Nice[1], P. B. Demorest[2], R. D. Ferdman[3], M. E. Gonzalez[4], S. M. Ransom[2], I. H. Stairs[4], NANOGrav

[1]*Lafayette College,* [2]*NRAO,* [3]*University of Manchester, United Kingdom,* [4]*University of British Columbia, Canada.*

9:00 AM - 6:30 PM

The NANOGrav consortium uses the Arecibo Observatory and the Green Bank Telescope to make high-precision timing observations of millisecond pulsars. This program is motivated both by the search for a gravitational wave background as well as more traditional pulsar timing applications such as measuring binary orbits to test theories of gravitation and measure neutron star masses. The observing program grows as new millisecond pulsars are discovered; presently 38 sources are under observation (19 each at Arecibo and Green Bank, with an overlap of 2 sources). All sources are observed at monthly intervals at two radio frequencies. We will discuss the observing program and data analysis. We present results from analysis of 5 years of data on 17 pulsars, including our measured upper limit to the gravitational wave background.

146.17 – **EVLA Follow-Up Observations of Gravitational Wave Burst Candidates**

Louis Dartez[1]

[1]*University of Texas Brownsville.*

9:00 AM - 6:30 PM

Certain transient sources of gravitational-wave radiation are expected to release large amounts of electromagnetic radiation. An "afterglow" of long-wavelength electromagnetic emissions may follow the initial burst. We have performed radio observations using the Expanded Very Large Array (EVLA) to follow up gravitational-wave burst candidates from the LIGO and Virgo gravitational wave detectors in Fall 2010. This poster outlines the key parts in rapid radio follow-ups as well the subsequent analysis of such triggers.

146.18 – **Observing Massive Black-hole Binaries With A Redesigned Lisa**

Sean T. McWilliams[1]

[1]*Princeton University.*

9:00 AM - 6:30 PM

In response to recent events in NASA and ESA, which necessitate the redesign of the Laser Interferometer Space Antenna (LISA) to lower its cost, we present results of a design study that evaluates the impact of various redesigns on the study of massive black-hole binaries (MBHB). As a result of the shift in sensitivity towards higher frequencies in all of the redesigns, the final merger signal will be even more critical for characterizing the coalescence of MBHBs. We assess the achievable parameter accuracy of MBHB measurements with various redesign options, and how well we expect the final design choices to perform. We include spinning mergers with higher harmonics in our calculation, which was never previously included in LISA calculations, and highlights the need to include all of the available physics in order to recover any performance lost in the redesign.

146.19 – **Visualizing the Effect of Gravitational Waves on Pulsar Arrival Times**

Grady Lunsford[1], R. H. Price[1]

[1]*University of Texas at Brownsville.*

9:00 AM - 6:30 PM

A gravitational wave between a pulsar and a radio telescope imposes a distinct pattern on the pulse arrival times. This effect is difficult to understand and to picture due to the complexity of the underlying theory and the lack of any absolute coordinates for spacetime. In this poster, soon to be a minor motion picture, the effect can be understood as the gravitational-wave modulation of distances between packets of photons(pulses) emitted. This work is funded by the National Science Foundation.

146.20 – **Detection Methods for Continuous Gravitational Waves using Pulsar Timing Data**

Justin Ellis[1], F. Jenet[2], X. Siemens[1]

[1]*University of Wisconsin Milwaukee,* [2]*University of Texas Brownsville.*

9:00 AM - 6:30 PM

Gravitational Waves (GWs) are tiny ripples in the fabric of space-time predicted by Einstein's General Relativity. Pulsar timing arrays (PTAs) are well poised to detect low frequency (10^{-9} - 10^{-7} Hz) GWs in the near future. There has been a significant amount of research into the detection of a stochastic background of GWs from supermassive black hole binaries (SMBHBs). Recent work has shown that single continuous sources standing out above the background may be detectable by PTAs operating at a sensitivity sufficient to detect the stochastic background. The most likely sources of continuous GWs in the pulsar timing frequency band are extremely massive and/or nearby SMBHBs. In this poster we present detection strategies including various forms of matched filtering and power spectra addition. We will discuss the implementation of these methods into a fully functional data analysis pipeline that will be used both for detection and parameter estimation of signals in real pulsar timing data.

146.21 – **Observing Big Black Holes with a Small LISA**

Neil J. Cornish[1], R. Lang[2], E. Berti[3]

[1]*Montana State Univ.,* [2]*Washington University,* [3]*University of Mississippi.*

9:00 AM - 6:30 PM

Budgetary constraints have forced NASA and the European Space Agency to consider downscaled designs for a future Laser Interferometer Space Antenna (LISA). Reducing the size of the detector array and reducing the number of laser links are two of the most effective cost saving measures. These changes reduce the information that can be

gathered from the inspiral of massive black holes. However, we find that including the previously neglected merger and ringdown portion of the full

binary black hole waveform can significantly improve the science return. A small LISA mission can deliver big science.

146.22 – **Spectral Analysis of Timing Noise in NANOGrav Pulsars**

Delphine Perrodin[1], F. A. Jenet[2], A. N. Lommen[1], L. S. Finn[3], P. B. Demorest[4]

[1]*Franklin & Marshall College,* [2]*University of Texas at Brownsville,* [3]*The Pennsylvania State University,* [4]*National Radio Astronomy Observatory.*

9:00 AM - 6:30 PM

The NANOGrav collaboration seeks to detect gravitational waves from distant supermassive black hole sources using a pulsar timing array. In order to search for gravitational waves, it is necessary to have a good characterization of the timing noise for each pulsar of the pulsar timing array. Red noise is common in millisecond pulsars, and we need to quantify how much red noise is present for each pulsar. This can be done by looking at the power spectra of the pulsar timing residuals. However because the pulsar data are non-uniformly sampled, one cannot simply do a Fourier analysis. Also, commonly used least-square fitting methods such as the Lomb-Scargle analysis are not adequate for steep red spectra. Instead, we compute the power spectra of NANOGrav pulsar timing residuals using the Cholesky transformation, which eliminates spectral leakage. This is done with the help of the TEMPO2 ``SpectralModel'' plugin developed by William Coles and George Hobbs.

146.23 – **Gravitational Wave Hotspots**

Joseph Simon[1]

[1]*Franklin and Marshall College.*

9:00 AM - 6:30 PM

Pulsar timing arrays continue to play a major role in the direct detection efforts of gravitational waves. As our understanding of Pulsar timing arrays (PTAs) increases we begin to wonder where detectable gravitational waves are occurring in the local sky. In an attempt to create that picture, we have compiled galactic databases and created a map of predicted gravitational power vs sky position in hopes of discovering if regions of enhanced gravitational wave power density are likely to exist. These "hotspots" could give a better idea of where to tune our PTAs in the sky and help give a observational direction to detection efforts.

146.24 – **Concepts For A Space-based Gravitational-wave Observatory (SGO)**

Robin T. Stebbins[1], Gravitational Wave Concept Definition Team

[1]*NASA GSFC.*

9:00 AM - 6:30 PM

The low-frequency band (0.0001 - 1 Hz) of the gravitational wave spectrum has the most interesting astrophysical sources. It is only accessible from space. The Laser Interferometer Space Antenna (LISA) concept has been the leading contender for a space-based detector in this band. Despite a strong recommendation from Astro2010, constrained budgets motivate the search for a less expensive concept, even at the loss of some science. We have explored the range of lower-cost mission concepts derived from two decades of studying the LISA concept. We describe LISA-like concepts that span the range of affordable and scientifically worthwhile missions, and summarize the analyses behind them.

146.25 – **The LISA Pathfinder Mission**

James Thorpe[1], P. W. Mc. Namara[2], LISA Pathfinder Team

[1]*NASA GSFC,* [2]*ESA ESTEC, Netherlands.*

9:00 AM - 6:30 PM

LISA Pathfinder is a dedicated technology demonstration space mission for the Laser Interferometer Space Antenna (LISA), a NASA/ESA collaboration to operate a space-based observatory for gravitational waves in the milliHertz band. Although the formal partnership between the agencies was dissolved in the Spring of 2011, both agencies are actively pursuing concepts for LISA-like gravitational wave observatories. These concepts take advantage of the significant technology development efforts that have already been made, especially those of the LISA Pathfinder mission. LISA Pathfinder, which is in the late stages of implementation, 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. We will present the current status of the LISA Pathfinder mission and associated activities.

146.26 – **Plans For A Next Generation Space-based Gravitational-wave Observatory (NGO)**

Jeffrey C. Livas[1], R. T. Stebbins[1], O. Jennrich[2], NGO Mission Development Team

[1]*NASA Goddard Space Flight Center,* [2]*European Space Agency ESTEC, Netherlands.*

9:00 AM - 6:30 PM

The European Space Agency (ESA) is currently in the process of selecting a mission for the Cosmic Visions Program. A space-based gravitational wave observatory in the low-frequency band (0.0001 - 1 Hz) of the gravitational wave spectrum is one of the leading contenders. This low frequency band has a rich spectrum of astrophysical sources, and the LISA concept has been the key mission to cover this science for over twenty years. Tight budgets have recently forced ESA to consider a reformulation of the LISA mission concept that will allow the Cosmic Visions Program to proceed on schedule either with the US as a minority participant, or independently of the US altogether. We report on the status of these reformulation efforts.

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147 – Undergraduate Research & Education

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

147.01 – **Astrobites: The Astro-ph Reader's Digest For Undergraduates**

Elisabeth Rose Newton[1], S. Kohler[2], D. Gifford[3], A. L. Plunkett[4], Astrobites Team

[1]*Harvard University,* [2]*University of Colorado at Boulder,* [3]*University of Michigan,* [4]*Yale University.*

9:00 AM - 6:30 PM

Astrobites (http://astrobites.com) is a daily blog aimed primarily at undergraduates interested in astrophysical research and written by a team of graduate students from around the country. Every day we present a journal article recently posted to astro-ph in a brief format that is accessible to anyone with a general background in the physical sciences. In addition to summarizing new work, Astrobites provides valuable context for readers 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 will discuss the Astrobites format, readership statistics and the results of our October reader survey (117 responses). The Astrobites blog is currently receiving 17000 on-site hits per month with an average of 600 all-time views per post. 17% of our readers are undergraduate students and 34% are graduates, while researchers and astronomy enthusiasts make up the remainder in equal parts. Out of the 60 students surveyed, 75% plan on a career in research in astrophysics.

EN and DG acknowledge support from the National Science Foundation through Graduate Research Fellowships.

147.02 – **The Arecibo Remote Command Center: Undergraduate and High School Students Exploring Astrophysics**

Andy Miller[1]

[1]*University of Texas-Brownsville.*

9:00 AM - 6:30 PM

The University of Texas-Brownsville (UTB) is home to the Arecibo Remote Command Center (ARCC). The ARCC is a virtual control room where researchers and undergraduate students_with the assistance of local high school students_control in real time the Arecibo Observatory_the world's largest single dish radio telescope. This poster presents a general outline of ARCC programs and recent accomplishments.

147.03 – **The Summer Undergraduate Research Internship Program at the Pisgah Astronomical Research Institute**

J. Donald Cline[1], M. Castelaz[1], C. Whitworth[1], D. Clavier[1], L. Owen[1], T. Barker[1]

[1]*Pisgah Astronomical Research Institute.*

9:00 AM - 6:30 PM

Pisgah Astronomical Research Institute (PARI) offers summer

undergraduate research internships. PARI has received support for the internships from the NC Space Grant Consortium, NSF awards for public science education, 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 7 funded students participated in 2011. Mentors for the interns include PARI's Science, Education, and Information Technology Directors and visiting faculty who are members of the PARI Research Affiliate Faculty program. Students work with mentors on radio and optical astronomy research, electrical engineering for robotic control of instruments, software development for instrument control and software for citizen science projects, 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. Several of the students have presented their results at AAS Meetings. We will present a summary of specific research conducted by the students with their mentors, the logistics for hosting the PARI undergraduate internship program, and plans for growth based on the impact of an NSF supported renovation to the Research Building on the PARI campus.

147.04 – **The California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE): Partnering Students to Astronomy at the University of Arizona's Astronomy Camp**

Hector Saldivar[1], D. McCarthy[2], A. L. Rudolph[1]

[1]*Dept. of Physics and Astronomy, California State Polytechnic University,* [2]*Steward Observatory, The University of Arizona.*

9:00 AM - 6:30 PM

The California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE) is an NSF-funded partnership between the Astronomy Program at Cal Poly Pomona and the University of Arizona Steward Observatory designed to promote participation of underrepresented minorities, including women, in astronomy research and education. By means of this program, Cal Poly Pomona undergraduates that are either Physics majors or minors are qualified to participate in the program alongside graduate students from the University of Arizona as a camp counselor at the University of Arizona's Astronomy Camp, one of the elite astronomy programs worldwide. Students that participate in the CAMPARE program are granted an opportunity to work in a hands-on environment by teaching astronomy to students from all over the world in a highly structured environment. The CAMPARE student selected for this program in Summer 2011 worked under the supervision of Dr. Don McCarthy, professor at the University of Arizona and Astronomy Camp director for over 20 years, learning to lead a group of students through daily activities and ensure that the students are learning to their maximum potential. Through this experience, the CAMPARE student learned to capture students' interest in astronomy and was introduced to real life teaching, which has helped prepare him for future experiences to come. We acknowledge the NSF for funding under Award No. AST-0847170, a PAARE Grant for the Calfornia-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE).

147.05 – **A Telescope Tale of Two Cities: Flagstaff & Boston: One NSF REU Supplement's Impact on 90 Students and a Dean**

Dan P. Clemens[1]

[1]*Boston Univ..*

9:00 AM - 6:30 PM

One key educational challenge we face is to increase the engagement of undergraduate non-science majors with the excitement of research and discovery in science. Astronomers well know that a night on a large telescope at a dark site is deeply transformative, as well as informative. At Boston University, we have the telescope and mountain, but how can real research involve more than a handful of students from a large, introductory, non-majors lecture-based course? We attempted to answer this question using the Fall 2010 Astronomy 102 ("The Astronomical Universe") non-majors offering as a test bed. Key components of our program were a field trip to the 1.8m Perkins telescope in Flagstaff, AZ for 12 students (and a dean), live video links between the 70+ students in Boston and the students at the telescope, small group projects, group presentations to the entire class, and funding from the National Science Foundation.

Partially supported by an NSF REU supplement to AST 09-07790 and time granted under the Boston University - Lowell Observatory Perkins Telescope partnership.

147.06 – **Rationale and Initial Design for a Virtual Undergraduate Internship in Astronomy**

Katie Berryhill[1], T. F. Slater[2], S. J. Slater[2]

[1]*American Public University System,* [2]*University of Wyoming.*
9:00 AM - 6:30 PM

In recent decades, research experiences for undergraduates (REUs) programs have provided students with opportunities to spend a summer working on a research project with a faculty mentor. The aim of these programs has generally been to take up the challenge of the Boyer-2 report to introduce research-based learning into the undergraduate experience (Boyer 1998). Recent efforts have been aimed at encouraging women and underrepresented minorities to pursue STEM careers. With the advent of successful models for online degree programs that can add to the STEM workforce pipeline, there is now the possibility of expanding these research experiences to include the new diverse demographic of previously untapped online learners. Many online learners are working adults, and therefore do not have the same flexibility as traditional undergraduates to attend a summer REU at another institution, nor do they have the opportunity for internships at their home institution.

This project is intended to leverage significant developments in rapidly emerging social media; investments in Internet-accessible telescopes for professional and amateur use; and contemporary advances in the learning sciences to build pathways through long-term, collaborative, astronomy research projects. The first stage involves developing initial research protocols and online mentoring infrastructures for establishing an ongoing national program for virtual astronomy internships for undergraduate STEM majors. Underlying this project is a plan for students to work collaboratively alongside active professional and amateur astronomers to conduct original research using remotely controlled and robotic telescopes. We anticipate that by the start of this project, more than 100 robotic and remotely controlled telescopes will exist around the world (mo-www.harvard.edu/OWN, aavso.org/aavsonet, and lcogt.net among others) providing continuous world-wide coverage. We plan to test and iteratively build a successful infrastructure for students to take advantage of these and other rapidly emerging resources and support an expansion of the STEM career workforce.

147.07 – Creating A Light Curve Using Gathered Data

Joseph Wiggs[1], S. A. Stolarz[1], R. W. DePorto[1], W. J. Shake[1], M. Piper[1], T. R. Linder[2], R. Holmes[2], J. Conwell[2]

[1]*Lincoln-Way North High School,* [2]*Eastern Illinois University.*
9:00 AM - 6:30 PM

Our group of students with the support of educators and astronomers carried out a program to do astrometric and photometric analysis on the asteroid 2000 SO1 with the objective of obtaining a more in depth analysis of this asteroid and publishing light curve data describing the period of the asteroid. We chose our target asteroid using the minor planet center database, choosing an object that would have an acceptable Right Ascension, Declination, magnitude, and air mass for the ARO (Astronomical Research Observatory)-30 inch telescope operated by the SKYNET program. Our journey began with using Astrometrica for the IASC/WISE Program to identify and find new asteroids in the sky and add data to the Minor Planet Center Database. We then used MPO (Minor Planet Observatory) Canopus to form a light curve and conduct a fourier analysis on an example asteroid to familiarize ourselves with the program and used the program again to conduct fourier analysis on asteroid 2000 SO1. The educational goal in mind was to (a) learn the process of collecting and analyzing data using Astrometrica, MPO Canopus, the Minor Planet Center, and SKYNET and (b) create a poster to display the steps used in the process of surveying taken images and the production of a light curve. We collected 300 images a night, while discarding all the corrupted images, until we had enough data to accurately represent the object.Our work was successful due to resources from; Eastern Illinois University's Physics Department, the Astronomical Research Observatory, the University of Chicago's Yerkes Observatory, the SKYNET network, NASA's IASC/WISE (International Astronomical Search Collaboration/ Wide-Field Infrared Survey Explorer), NITARP (NASA/IPAC Teacher Archive Research Program) and Lincoln-Way North High School.

147.08 – **Global Warming Education for Astro 101 Classes**

James D. Lowenthal[1], E. F. Guinan[2], P. Knezek[3], J. H. Lacy[4], P. J. Marshall[5], B. Rodgers[6], E. Rykoff[7], K. Sheth[8]

[1]*Smith College,* [2]*Villanova Univ.,* [3]*NOAO/WIYN Obs.,* [4]*University of Texas,* [5]*University of Oxford, United Kingdom,* [6]*Gemini Observatory, Chile,* [7]*UCSB,* [8]*NRAO.*
9:00 AM - 6:30 PM

The AAS Sustainability Committee (SC) aims to reduce the ecological footprint of the AAS. The SC has identified three major areas of concern on which to focus for the coming year: (1) AAS Meetings, which are energy-intensive because of their associated travel, lodging, and conference center needs; (2) other travel, including to observing runs, team meetings, and conferences -- some of that travel could reasonably be replaced with teleconferencing options, which we are exploring; and (3) education. There will be a special session at this meeting devoted to helping astronomy professors include global warming in their Astro 101 classes. Several seasoned educators will share their tips and provide online resources such as PowerPoint slides and figures on climate change.

147.09 – **Computing Across the Physics and Astrophysics Curriculum**

Kathy DeGioia Eastwood[1], M. James[1], E. Dolle[1]

[1]*Northern Arizona University.*
9:00 AM - 6:30 PM

Computational skills are essential in today's marketplace. Bachelors entering the STEM workforce report that their undergraduate education does not adequately prepare them to use scientific software and to write programs. Computation can also increase student learning; not only are the students actively engaged, but computational problems allow them to explore physical problems that are more realistic than the few that can be solved analytically. We have received a grant from the NSF CCLI Phase I program to integrate computing into our upper division curriculum. Our language of choice is Matlab; this language had already been chosen for our required sophomore course in Computational Physics because of its prevalence in industry. For two summers we have held faculty workshops to help our professors develop the needed expertise, and we are now in the implementation and evaluation stage. The end product will be a set of learning materials in the form of computational modules that we will make freely available. These modules will include the assignment, pedagogical goals, Matlab code, samples of student work, and instructor comments. At this meeting we present an overview of the project as well as modules written for a course in upper division stellar astrophysics. We acknowledge the support of the NSF through DUE-0837368.

147.10 – **An Inexpensive Method to use an Ocean Optics Spectrometer for Telescopic Spectroscopy**

Berger Joel[1], B. E. K. Sugerman[1]

[1]*Goucher College.*
9:00 AM - 6:30 PM

We present a relatively-inexpensive method for using an Ocean Optics spectrometer for telescopic spectroscopy. The Ocean Optics spectrometer is a highly-sensitive, affordable and versatile fiber-optic spectrometer that can be used in a variety of physics and astronomy classes and labs. With about $275 and a small amount of machining, this spectrometer can be easily adapted for any telescope that accepts 2" eyepieces. We provide the equipment list, machining specs, and calibration process, as well as sample stellar spectra. This work was supported by the Department of Physics and Astronomy and the Office of the Provost of Goucher College.

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148 – The LITTLE THINGS Survey

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

148.01 – **The Little Things Survey**

Deidre Ann Hunter[1], LITTLE THINGS team

[1]*Lowell Obs..*
9:00 AM - 6:30 PM

We have assembled a multi-wavelength dataset on 41 relatively normal, nearby (<10 Mpc) gas-rich dwarf irregular galaxies for the purpose of determining the drivers for star formation in these systems. This project is called LITTLE THINGS (Local Irregulars That Trace Luminosity Extremes, The HI Nearby Galaxy Survey). Our data include GALEX UV images, ground-based UBV and Halpha images, some ground-based JHK images, Spitzer archival mid-IR images, and HI-line maps. The HI maps, obtained with the VLA, go deep (12/6/2 hrs in B/C/D arrays) and are characterized by high spectral resolution (</=2.6 km/s) and high angular resolution (typically 6", which is 110 pc at the average distance of our sample). Our datasets trace the stellar populations, gas content and structure, dynamics, and star formation indicators in the galaxies, and are being used to answer questions about star formation in dwarf galaxies. We are making the HI data available to the public for the first time January 2012. Here we give a taste of the data that are available.

The LITTLE THINGS team is grateful to the National Science Foundation for funding through grants AST-0707563, AST-0707426, AST-0707468, and AST-0707835 to DAH, BGE, CES, and LMY.

148.02 – **Star Formation in LITTLE THINGS: HI Line Profile Analysis of Nearby Dwarfs**

Phil Cigan[1], L. Young[1], D. Hunter[2]

[1]*New Mexico Tech,* [2]*Lowell Observatory.*
9:00 AM - 6:30 PM

Dwarf galaxies are unique laboratories for studying the process of star formation in metal-poor environments. The comprehensive data of the LITTLE THINGS project provide an excellent tool to probe the relation between star formation and the interstellar media of these systems. By analyzing HI velocity dispersions for Gaussian (and modified Gaussian) profiles, we can separate the cold neutral medium (CNM) and warm neutral medium (WNM) phases of the ISM. From that, we can determine which areas and conditions are more favorable for star formation. Comparison with data from other wavelengths such as H-alpha, UV, and FIR will test the predictions of the HI line profile analysis.

148.03 – **Color Profile Trends of Dwarf Galaxies**

Kimberly A. Herrmann[1], LITTLE THINGS team

[1]*Lowell Observatory.*

9:00 AM - 6:30 PM

Radial stellar surface brightness 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 surface brightness profile breaks are also found in dwarf disk galaxies, but with an additional category: (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. Furthermore, color trends reveal information about possible stellar population changes at the breaks. Here we show color trends for the four profile types from a large multi-wavelength photometric study of dwarf disk 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.

We gratefully acknowledge funding for this research from the National Science Foundation (AST-0707563).

148.04 – **The Extent of the Atomic Gas in Spiral and Dwarf Irregular Galaxies**

Elias Brinks[1], A. Portas[1], W. J. G. de Blok[2], R. C. Kennicutt[3], J. Sommer-Larsen[4], A. Usero[5], F. Walter[6]

[1]*Univ. of Hertfordshire, United Kingdom,* [2]*University of Cape Town, South Africa,* [3]*University of Cambridge, United Kingdom,* [4]*Niels Bohr Institute, Denmark,* [5]*Observatorio Astronómico Nacional, Spain,* [6]*Max–Plank–Institut für Astronomie, Germany.*

9:00 AM - 6:30 PM

We use a subsample of galaxies observed as part of THINGS (The H I Nearby Galaxy Survey) to investigate the H I extent of spiral galaxy disks. We revisit previous work on the extent of H I disks, showing the limitations set by insufficient linear resolution. We then exploit the high spatial and velocity resolution combined with good sensitivity of THINGS to investigate where the atomic gas disks in galaxies end and what might shape their outskirts. We find that the atomic gas surface density across most of the disk is constant at 5–10 x10^{20} cm^{-2} and declines at large radius. The general shape of the H I distribution can be described by a Sérsic-type function with a slope index, $n = 0.18 - 0.36$ and characteristic radius r_i. We introduce a column density threshold of 5 x 10^{19} cm^{-2} to define the extent of the gas disk. This limit is well within reach of modern instruments and is at the level where disk gas has reached on average 85% of its maximum extent. The H I column density at which the radial profiles turn over is found to be at too high a level for it to be caused by ionization by a meta-galactic UV field and we postulate that the H I extent is set by how galaxy disks form. This is corroborated by recent simulations of the evolution of the gas content and distribution in cosmological simulations that take into account the effect of supernovae and atomic radiative cooling. The resulting simulated radial profiles are remarkably similar to those observed, i.e., confirming that their overall shape is determined by galaxy evolution, ionization by the meta-galactic radiation only playing a role at column densities below a few x 10^{19} cm^{-2}.

148.05 – **Central Dark Matter Distribution In Dwarf Galaxies**

Se-Heon Oh[1], C. Brook[2], F. Governato[3], E. Brinks[4], L. Mayer[5], E. de Blok[6], A. Brooks[7], F. Walter[8]

[1]*CAASTRO, International Centre for Radio Astronomy (ICRAR), The Univ. of Western Australia, Australia,* [2]*Jeremiah Horrocks Institute, University of Central Lancashire, United Kingdom,* [3]*Astronomy Department, University of Washington,* [4]*Centre for Astrophysics Research, University of Hertfordshire, United Kingdom,* [5]*Institute for Theoretical Physics, University of Zurich, Switzerland,* [6]*Astronomy Department, Astrophysics, Cosmology and Gravity Centre (ACGC), University of Cape Town, South Africa,* [7]*Theoretical Astrophysics, California Institute of Technology,* [8]*Max-Planck-Institut f˙r Astronomie, Germany.*

9:00 AM - 6:30 PM

Central dark matter distribution in dwarf galaxies

Se-Heon Oh, Chris Brook, Fabio Governato, Elias Brinks, Lucio Mayer, W.J.G. de Blok, Alyson Brooks and Fabian Walter

We present high-resolution mass models of 7 nearby dwarf galaxies from “The HI Nearby Galaxy Survey” (THINGS) and compare these with those from hydrodynamic simulations of dwarf galaxies assuming a ΛCDM cosmology. The simulations include the effect of baryonic feedback processes, such as gas cooling, star formation, cosmic UV background heating and most importantly, physically motivated gas outflows driven by supernovae (SNe). For the THINGS dwarf galaxies, we derive the mass models for the dark matter component by subtracting the contribution from baryons, derived from our HI observations and using the “Spitzer Infrared Nearby Galaxies Survey” (SINGS) 3.6μm data, from the total kinematics, leaving only the contribution by the Dark Matter halo. In parallel, we perform dark matter mass modeling of the simulated dwarf galaxies in exactly the same way as the observed THINGS dwarf galaxies. From a direct comparison between the observations and simulations, we find that the dark matter rotation curves of the simulated dwarf galaxies rise less steeply in the inner regions than those of dark-matter-only simulations based on the ΛCDM paradigm, and are more consistent with those of the THINGS dwarf galaxies. In addition, the mean value of the logarithmic inner dark matter density slopes, α, of the simulated galaxies is approximately -0.4 ± 0.1, which is in good agreement with α = -0.29 ± -0.07 of the THINGS dwarf galaxies. This shows that the baryonic feedback processes in the simulations are efficient in flattening the initial cusps with α = -1.0 to -1.5 predicted from dark-matter-only simulations, and render the dark matter halo mass distribution more similar to that observed in nearby dwarf galaxies.

148.06 – **NGC 1569: Stellar and Gas Kinematics and Dark Matter Content**

Megan C. Johnson[1], S. Oh[2], H. Zhang[3], D. A. Hunter[4], E. Tollerud[5], B. Elmegreen[6], E. Brinks[7], LITTLE THINGS Team

[1]*NRAO - Green Bank,* [2]*University of Western Australia, Australia,* [3]*Lowell Observatory/Purple Mountain Observatory,* [4]*Lowell Observatory,* [5]*University of California - Irvine,* [6]*IBM T.J. Watson Research Center,* [7]*University of Hertfordshire, United Kingdom.*

9:00 AM - 6:30 PM

We present our results from long slit stellar spectroscopy from the KPNO 4-meter + Echelle spectrograph combined with high-resolution neutral hydrogen VLA data of NGC 1569. We examine the kinematics of the stars and gas in NGC 1569. In addition, we carefully measure the mass of the stars in NGC 1569 using a new SED fitting procedure. We compare the total mass in stars and gas to the dynamical mass derived from the maximum rotation speed and postulate that NGC 1569 may be dark matter deficient. However, when the rotation curve is compared to what is expected from ΛCDM cosmological simulations, it appears that the observed velocities in the outer disk of NGC 1569 agree with what is expected from an extended dark matter halo.

148.07 – **Fourier Transform Power Spectra Analysis of Dwarf Irregular Galaxies**

Hongxin Zhang[1], D. A. Hunter[2], LITTLE THINGS team

[1]*Lowell Observatory and Purple Mountain Observatory,* [2]*Lowell Observatory.*

9:00 AM - 6:30 PM

The LITTLE THINGS survey has obtained deep HI emission line maps with the data from VLA B, C and D array configurations for a representative sample of nearby dwarf irregular galaxies, and supplemented this with images from the FUV to the NIR. We present the fourier transform power spectra of the HI maps, FUV and NIR images for a subsample of nearly face-on (minor-to-major axis ratio > 0.8) LITTLE THINGS galaxies in order to examine structures within the galaxies' gas and stellar disks.The radial variations of the power spectra will be compared with global properties. We will also compare the relationship between the gas, star formation and stellar mass on different physical scales and at different radii, and discuss the possibility of using breaks in power-law power spectra to constrain the disk thickness.

The LITTLE THINGS team is grateful to the National Science Foundation for funding through grants AST-0707563, AST-0707426, AST-0707468, and AST-0707835 to DAH, BGE, CES, and LMY. HZ was partly supported by NSF of China through grants \#10425313, \#10833006 and \#10621303 to Professor Yu Gao.

148.08 – **Deep Radio Continuum Imaging Of The Dwarf Irregular Galaxy IC 10: Tracing Star Formation And Magnetic Fields**

Volker Heesen[1], U. Rau[2], M. P. Rupen[2], E. Brinks[1], D. A. Hunter[3]

[1]*University of Hertfordshire, United Kingdom,* [2]*NRAO,* [3]*Lowell Observatory.*

9:00 AM - 6:30 PM

We exploit the vastly increased sensitivity of the Expanded Very Large Array (EVLA) to study the radio continuum and polarization properties of the post-starburst, dwarf irregular galaxy IC10 at 6 cm, at a linear resolution of ~50 pc. We find close agreement between radio continuum and Halpha emission, from the brightest HII regions to the weaker emission in the disk. A quantitative analysis shows a strictly linear correlation,

where the thermal component contributes 50% to the total radio emission, the remainder being due to a non-thermal component with a surprisingly steep radio spectral index of between -0.7 and -1.0 suggesting substantial radiation losses of the cosmic-ray electrons. We confirm and clearly resolve polarized emission at the 10-20% level associated with a non-thermal superbubble, where the ordered magnetic field is possibly enhanced due to the compression of the expanding bubble. A fraction of the cosmic-ray electrons has likely escaped because the measured radio emission is a factor of 3 lower than what is suggested by the Halpha inferred SFR. V.H. is funded by the Science and Technology Facilities Council (STFC) via a rolling grant to the Centre for Astrophysics Research.

149 – HEAD The Variable and Surprising Gamma-ray Sky

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

149.01 – **The Search for Type 1 X-ray Bursts with Fermi/GBM**

Peter Jenke[1], M. Linares[2], V. Connaughton[3], A. Camero-Arranz[4], M. H. Finger[4], C. A. WIlson-Hodge[5], A. Van Der Horst[4], Fermi-GBM X-ray burst collaboration

[1]MSFC/NPP, [2]MIT, [3]UAH, [4]USRA, [5]NASA/MSFC.

9:00 AM - 6:30 PM

We discuss the first results of the Fermi-GBM all-sky search for X-ray bursts. The very large field of view and X-ray response of the Fermi-GBM make it a

unique instrument to study rare, bright and short-lived X-ray bursts. We are performing a systematic search that exploits such capabilities. We present results on long/intermediate type I X-ray bursts, an unusual kind of thermonuclear bursts from accreting neutron stars, and show how Fermi-GBM is giving, for the first time, robust measurements of their recurrence time.

149.02 – **Contents and Construction of the Second Fermi Large Area Telescope Catalog of Gamma-ray Pulsars**

Tyrel J. Johnson[1], D. Parent[2], O. Celik[3], J. E. Grove[4], Fermi LAT Collaboration, Pulsar Timing Consortium

[1]NRC Fellow at NRL, [2]GMU resident at NRL, [3]NASA GSFC CRESST, [4]NRL.

9:00 AM - 6:30 PM

Using six months of survey data, the first Fermi Large Area Telescope (LAT) catalog of gamma-ray pulsars detailed the spectral and light curve characteristics of forty-six rotation-powered pulsars observed to pulse above 100 MeV. With three years of survey data and enhanced analysis techniques, the second LAT catalog of gamma-ray pulsars promises to shed more light on the pulsing gamma-ray sky. The number of known gamma-ray pulsars has more than doubled and separated into three, equally numerous classes: young radio-selected, young gamma-ray selected, and millisecond pulsars. We will outline the methods used to search for pulsed signals in the LAT data, the criteria by which pulsed signals were considered significant, and the basic content of the catalog. Part of this work is performed at NRL, sponsored by NASA DPR S-15633-Y.

149.03 – **Study of Fast Pulsars Using Continuous Time Tagged Events from the GBM Detectors**

Narayana P. Bhat[1], M. H. Finger[2], P. A. Jenke[3], A. Camero-Arranz[2], C. A. Wilson-Hodge[3], M. S. Briggs[1]

[1]Univ. of Alabama in Huntsville, [2]USRA, [3]Marshall Space Flight Center.

9:00 AM - 6:30 PM

The time tagged event (TTE) data from the Gamma-ray Burst Monitor (GBM) onboard the Fermi Gamma-ray Space Telescope have excellent time resolution of 2 usec. Untriggered TTE data from the 12 Sodium Iodide (NaI which operate in the gamma-ray energy range: 10-1000 keV) and 2 Bismuth Germanate (BGO which operate in the gamma-ray energy range: 0.15-40 MeV) detectors have been produced since July 2010. These are being generated only within pre-defined boxes in the Fermi orbit, which are designed for the study of Terrestrial Gamma-ray Flashes (TGF). Using these data we obtain pulse profiles for the Crab pulsar by the well known epoch folding technique. The phasogram exhibits both the main and the inter-pulse as expected. Our sensitivity calculations show that we may be able to produce similar pulse profiles for weaker fast pulsars like the Vela pulsar and Geminga using the continuous TTE data. We need to

integrate the data over longer (~ 10^6 s) exposure times in order detect weaker signals from these pulsars. This would entail the production of TTE data continuously through out the orbit. The measurement of pulsed fluxes from these pulsars in the GBM energy range will enhance the Science capability of Fermi. In addition, we can also search for untriggered weak GRBs as well as other galactic transients and investigate their location and spectral information.

149.04 – **An Extraordinary Flare in 3C454.3 in November 2010**

Ann E. Wehrle[1], A. Marscher[2], S. Jorstad[2], M. Gurwell[3]

[1]Space Science Institute, [2]Boston University, [3]Harvard-Smithsonian Center for Astrophysics.

9:00 AM - 6:30 PM

In November 2010, the blazar 3C454.3 flared to extraordinary brightness. Luckily for us, it was just a few days before the visibility window for Herschel infrared observations opened. We present multiwavelength data obtained from November 2010 through January 2011, centered on our Target of Opportunity Herschel observations at five submillimeter and far-infrared bands. We combined the Herschel data with Fermi LAT gamma-ray data, Swift X-ray, ultraviolet and optical data, SMA millimeter data, optical and near-infrared data and other ground-based data to form a series of multiwavelength spectral energy distributions spanning nearly two months. Multiwavelength light curve analysis and modelling allow us to quantify time-dependent relationships between synchrotron-emitting charged particle distributions, seed photons, the inverse-Compton gamma-ray emission and the jet physical conditions as the flare evolved.

Funding has been provided by NASA through grants from the US Herschel Science Center and the Fermi Guest Investigator Program.

149.05 – **Multi-wavelength Observations of Cygnus X-1**

Angelo Varlotta[1], VERITAS Collaboration

[1]Smithsonian Astrophysical Observatory.

9:00 AM - 6:30 PM

The TeV detection of LS I+61°303, LS 5039, PSR B1259-63 and HESS J0632+057 has confirmed x-ray binaries (XRB) as a new class of very-high-energy gamma-ray sources. XRB that possess stellar-mass black holes and collimated relativistic outflows are referred to as microquasars. Cygnus X-1 fits well the definition of microquasar. Based on their similarities to AGN, which account for a large population of GeV/TeV sources, microquasars constitute a potential class of gamma-ray emitters. Just as in AGN, jets are the most likely sites for particle acceleration and gamma-ray production in microquasars. We present the results of the simultaneous observations of Cygnus X-1, within the context of the latest multi-wavelength campaign, with specific focus on the VERITAS (TeV) and Fermi (GeV) results.

VERITAS research is supported by grants from the U.S. Department of Energy, the U.S. National Science Foundation and the Smithsonian Institution, by NSERC in Canada, by Science Foundation Ireland and by STFC in the UK.

149.06 – **Polarized X-ray Synchrotron Emission in Blazars**

Matthew G. Baring[1], T. J. Sarkar[1]

[1]Rice University.

9:00 AM - 6:30 PM

Multiwavelength observations of blazars are now providing, for the first time, clean diagnostics on the shock acceleration environment in the jets/outflows in these extragalactic sources. This is enhanced by new spectroscopic information from the Fermi Gamma-Ray Space Telescope that constrains the power-law index of the radiating particle population. This paper explores complementary polarimetric consequences of such diagnostics that can be probed by NASA's new SMEX X-ray mission, GEMS. Polarization signals in shocked blazar jets couple directly to the magnetic field geometry and the inherent particle anisotropy in these relativistic discontinuities. These anisotropies and the photon spectral indices are interconnected, so that simultaneous X-ray/gamma-ray spectroscopic measurements and X-ray polarization determinations enable diagnostics on the field geometry. Here we highlight some representative polarization predictions for slab and helical field morphologies, including temporal swings in position angle, to encapsulate the possibilities for the GEMS blazar science legacy.

149.07 – **Discovery of Evidence for Correlated X-ray/GeV Variability in the Feb. 2010 Flare of Mrk 421**

Grzegorz Maria Madejski[1], B. Giebels[2], S. Fegan[2], D. Horan[2], J. Chiang[1], Fermi LAT Collaboration

[1]Stanford Linear Accelerator Ctr., [2]LLR Ecole Polytechnique, France.

9:00 AM - 6:30 PM

We report on observations of the high-synchrotron-peaked BL Lac (HBL) Markarian 421 during a bright X-ray flaring period in February 2010. Combining data in the GeV band, obtained by the Fermi Large Area Telescope, with data in the X-rays, obtained by the RXTE, Swift, and MAXI observatories, we find evidence for correlated variability between the X-ray and GeV emission for the first time in an HBL. Including data from the UVOT instrument aboard Swift, we model the spectral energy distribution of the source in the pre-flare, flare and post-flare time periods using the standard synchrotron self-Compton model. In the context of these models, the GeV and X-ray emission arise from electrons with significantly different energies in the particle distributions that are inferred from the models. We discuss the constraints that the correlated X-ray/GeV temporal behavior places on the properties of the emitting plasma during this flare.

149.08 – **Exploring Physical Emission Processes via Spectral Fits to Bright Fermi Gamma-Ray Bursts**

James M. Burgess[1], R. Preece[1], M. Baring[2], Fermi GBM Science Team

[1]*University of Alabama in Huntsville,* [2]*Rice University.*

9:00 AM - 6:30 PM

Discerning the radiative dissipation mechanism for prompt emission in Gamma-Ray Bursts (GRBs) requires detailed spectroscopic modeling that straddles the vFv peak in the 100 keV - 1 MeV range. Historically, empirical fits such as the popular Band function have been employed with considerable success in interpreting the observations. While extrapolations of the Band parameters can provide some physical insight into the emission mechanisms responsible for GRBs, these inferences do not provide a unique way of discerning between models. By fitting physical models directly this degeneracy can be broken, eliminating the need for empirical functions; our analysis here offers a first step in this direction. One of the oldest, and leading, theoretical ideas for the production of the prompt signal is the synchrotron shock model (SSM). Here we explore the applicability of this model to several bright Fermi GBM bursts. Our investigation implements, for the first time, thermal and non-thermal synchrotron emissivities in the RMFIT forward-folding spectral analysis software often used in GBM burst studies. We find that these synchrotron emissivities, together with a blackbody shape, provide at least as good a match with the data as the Band GRB spectral fitting function. This success is achieved in both time-integrated and time-resolved spectral fits.

149.09 – **The Fermi GBM Gamma-Ray Burst Spectral Catalog: The First Two Years**

Adam Goldstein[1], J. M. Burgess[1], R. D. Preece[1], Fermi/GBM Science Team

[1]*University of Alabama in Huntsville.*

9:00 AM - 6:30 PM

We present a catalog of systematic spectral analyses of GRBs detected by the Fermi Gamma-Ray Burst Monitor (GBM) during its first two years of operation. This catalog contains two types of spectra extracted from 487 GRBs, and by fitting four different spectral models, this results in a compendium of over 3800 spectra. The models were selected based on their empirical importance to the spectral shape of many GRBs, and the analysis performed was devised to be as thorough and objective as possible. We describe our procedure and criteria for the analyses, and present the bulk results in the form of parameter distributions. This catalog should be considered an official product from the Fermi/GBM Science Team, and the data files containing the complete results are available from the High-Energy Astrophysics Science Archive Research Center (HEASARC).

149.10 – **Fermi-LAT Observations of Gamma-ray Bursts**

Judith L. Racusin[1], Fermi LAT and GBM Collaborations

[1]*NASA/GSFC.*

9:00 AM - 6:30 PM

Fermi-LAT has provided a unique new dataset of high energy observations of Gamma-ray Bursts, which has led to many recent theoretical advancements and challenges. We present an overview of the first 3 years of observations in the 100 MeV - 300 GeV LAT bandpass including the detection of ~30 GRBs and limits on those not detected but within the LAT field-of-view. Several new features are common in the temporal and spectral behavior of these bursts including a delayed onset compared to the keV-MeV emission, an extra spectral power-law component sometimes in the high-energy spectrum, and extended emission lasting significantly longer than the lower-energy prompt emission possibly associated with the broadband afterglow.

149.11 – **Multi-Component Spectral Analysis of Bright Gamma Ray Bursts observed with the Fermi Gamma ray Space Telescope**

Sylvain Guiriec[1]

[1]*NASA Goddard Space Flight Center.*

9:00 AM - 6:30 PM

The 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 in the keV-MeV energy range were adequately fit with the empirical Band function, which consists of two power laws (PLs) smoothly connected at a break energy. The Band function is usually associated to non-thermal emission processes. Spectral analysis over the broad energy range of GBM shows deviations from this function. These deviations are sometimes adequatelly fit with an additional PL extending from the lowest energy in GBM to the highest energy in GBM and LAT. We also recently clearly identified, for the first time, a physical thermal spectral component together with the non-thermal one. We present here the identification of multiple spectral components in the Fermi prompt emission spectra of some bright GRBs: a photospheric thermal component, a broken PL 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 of Fermi data, 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 in GBM and LAT. 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.

149.12 – **The Fermi GBM Gamma-Ray Burst Catalog: The First Two Years**

William Simon Paciesas[1], Fermi GBM Collaboration

[1]*Univ. of Alabama Huntsville.*

9:00 AM - 6:30 PM

The Fermi Gamma-ray Burst Monitor (GBM) is designed to enhance the scientific return from Fermi in studying gamma-ray bursts (GRBs). In its first two years of operation GBM triggered on 491 GRBs. We summarize the criteria used for triggering and quantify the general characteristics of the triggered GRBs, including their locations, durations, peak flux, and fluence. This catalog is an official product of the Fermi GBM science team, and the data files containing the complete results are available from the High-Energy Astrophysics Science Archive Research Center (HEASARC).

149.13 – **Observation of Terrestrial Gamma-ray Flashes with Fermi LAT**

J. Eric Grove[1], A. Chekhtman[2], Fermi LAT Collaboration, G. Fishman[3], M. Briggs[4], V. Connaughton[4], Fermi GBM Collaboration

[1]*Naval Research Laboratory,* [2]*George Mason University,* [3]*Marshall Space Flight Center,* [4]*University of Alabama Huntsville.*

9:00 AM - 6:30 PM

Terrestrial Gamma-Ray Flashes (TGFs) are millisecond bursts of high energy photons, electrons, and positrons originating in Earth's atmosphere and associated with powerful thunderstorms. The Fermi GBM has detected hundreds of TGFs, some with energies up to 40 MeV. Recent AGILE observations of photons up to ~100 MeV in TGFs pose a significant challenge to the relativistic runaway electron avalanche mechanism that is generally believed to be responsible for these bremsstrahlung gamma rays. With its large area, high segmentation, and low deadtime, the Fermi Large Area Telescope (LAT) is a powerful instrument for measuring the high energy emission of these short, intense transients. Here we present early results of a program of observing TGFs with the LAT.

149.14 – **Event-by-Event Errors: Using Covariance to Enhance the Fermi Sky**

Brendan Wells[1], W. McConville[2], T. Johnson[3], W. Atwood[1], S. Ritz[1]

[1]*University of California, Santa Cruz,* [2]*University of Maryland,* [3]*Goddard, NASA.*

9:00 AM - 6:30 PM

In the standard ground-based processing of Fermi LAT data, a detailed fit is done for each photon event. In addition to the best estimate of the direction, this also provides an estimate of the two-dimensional errors. Although this event-by-event error information in basic form has been included in the standard data release, it has not yet been utilized in science analysis because more development work is required. We show here the characteristics of these covariant errors when projected back onto the sky and discuss the potential science returns, including source finding, localization, and image analysis.

149.15 – **Detection Of Multi-photon Events With The Fermi-lat**

Eric Charles[1], Fermi-LAT Collaboration

[1]*SLAC.*

9:00 AM - 6:30 PM

One of the striking improvements in performance of the Fermi-LAT over previous gamma-ray missions is its "shutter speed". When viewed as a camera, the LAT has a shutter speed approximately equal to its trigger window width (600 ns) and a frame advance time set by the readout dead time (26.5 us).

The combination of speed and large effective area suggests the possibility of recording simultaneous photons. It has been indeed suggested that some astrophysical sources could produce coherent high-energy gamma rays. In addition, extraordinarily bright, short bursts from, for example, the evaporation of black holes could result in such multi-photon events.

However, searches for such exotic events are not possible with the current reconstruction algorithms. More specifically, the lack of calorimeter clustering and a background rejection tuned on single-photon events kills almost completely any sensitivity the LAT might have to see such events. We are addressing both of these deficiencies with the re-design of the LAT reconstruction software currently underway. The new calorimeter clustering algorithm recognizes and separates distinct energy depositions within it and this, coupled with the new tracker pattern recognition, will enable a search for multi-photon events.

149.16 – **Understanding and Using the Fermi Science Tools**

Eric L. Winter[1]

[1]*NASA GSFC.*
9:00 AM - 6:30 PM

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.

149.17 – **The Fermi Science Support Center**

Donald J. Horner[1], Fermi Science Support Center Team

[1]*NASA's GSFC.*
9:00 AM - 6:30 PM

The Fermi Science Support Center (FSSC) serves as the primary interface between the Fermi Gamma-ray Space Telescope mission and the scientific community. The FSSC supports the planning and scheduling of science observations and maintains an archive of all publicly accessible Fermi data. The FSSC also maintains and distributes data analysis software and associated documentation as well as providing technical and scientific support. In addition, the FSSC is administering the guest investigator program for NASA Headquarters and provides proposal preparation tools and documentation. We present an overview of the FSSC's role in each of these activities.

149.18 – **The Fermi Gamma-ray Space Telescope: Looking Towards The Future**

Julie E. McEnery[1], Fermi mission team

[1]*NASA's GSFC.*
9:00 AM - 6:30 PM

The Fermi Gamma-ray Space Telescope has been surveying the high-energy gamma-ray sky for the past three and a half years. Operating from 20 MeV to over 300 GeV, the Large Area Telescope (LAT) has discovered over a thousand new high-energy gamma-ray sources, uncovered many new classes of gamma-ray emitting objects, observed surprising variable and transient objects and placed limits on potential gamma-ray signatures of new physics. A second instrument, the gamma-ray burst monitor which operates from 8 keV to 40 MeV, has been busy detecting gamma-ray transients from thunderstorms, solar flares, magnetars and gamma-ray bursts. These observations have revolutionized our knowledge of the high energy universe. The mission has operated primarily in a survey observing mode, which enables the LAT to view the entire sky every 3 hours. However as the mission progresses there has been an increasing number of pointed mode observations to enhance the sensitivity at particularly interesting regions of the sky. All gamma-ray data is immediately made publicly available via the Fermi Science Support Center. In this poster, I will summarize the current status of the Fermi mission and operations, and will describe the new opportunities and science prospects with Fermi over the next five years.

149.19 – **Investigating the Unassociated Fraction in the Second Fermi-LAT Source Catalog**

Elizabeth C. Ferrara[1], LAT Collaboration

[1]*NASA/GSFC.*
9:00 AM - 6:30 PM

A significant fraction of gamma-ray sources detected by the Fermi Large Area Telescope are not associated with any known gamma-ray emitting object. These sources represent discovery space for new source classes, or new members of existing source classes. We discuss the spatial, spectral and temporal characteristics of the unassociated sources in the second Fermi-LAT source catalog (2FGL). We compare these distributions with the characteristics of the primary source classes (extragalactic vs. Galactic sources) to provide likely source classifications, and compare our results against the total predicted numbers of each source population. We also review the 1FGL unassociated source population, and discuss how changes in the catalog analysis have affected the resulting unassociated source sample.

149.20 – **Sources above 10 GeV in the Fermi Sky**

David John Thompson[1], P. Fortin[2], D. Paneque[3], Fermi Large Area Telescope Collaboration

[1]*NASA's GSFC,* [2]*Laboratoire Leprince-Ringuet, École polytechnique, France,* [3]*Max-Planck-Institut für Physik, München, Germany.*
9:00 AM - 6:30 PM

We searched for gamma-ray sources at energies above 10 GeV using data from the Large Area Telescope (LAT) accumulated during the first 3 years of the Fermi Gamma-ray Space Telescope mission. We found more than 400 sources, measured their spectra, quantified their variability, and studied their associations with cataloged sources at other wavelengths. We will describe the implications of this study for the populations of hard-spectrum gamma-ray emitters. Moreover, we will also highlight the subset of sources that are good candidates for detection at energies above 100 GeV with Cherenkov telescopes, which amount to about one third of the above list. This search complements the Second Fermi LAT catalog, which was based on 2 years' of data extending down to 100 MeV and included many sources with softer spectra.

149.21 – **Fermi Science Support Center Data Servers and Archive**

Thomas E. Stephens[1]

[1]*Wyle IS/Fermi Science Support Center.*
9:00 AM - 6:30 PM

The Fermi Science Support Center (FSSC) provides the scientific community with access to Fermi data and other products. The Gamma-Ray Burst Monitor (GBM) data is stored at NASA's High Energy Astrophysics Science Archive Research Center (HEASARC) and is accessible through their searchable Browse web interface. The Large Area Telescope (LAT) data is distributed through a custom FSSC interface where users can request all photons detected from a region on the sky over a specified time and energy range. Through its website the FSSC also provides planning and scheduling products, such as long and short term observing timelines, spacecraft position and attitude histories, and exposure maps. We present an overview of the different data products provided by the FSSC, how they can be accessed, and statistics on the archive usage since launch.

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150 – HAD III Poster Session

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

150.01 – **Acronical Risings and Settings**

Thomas A. Hockey[1]

[1]*University of Northern Iowa.*
9:00 AM - 6:30 PM

A concept found in historical primary sources, and useful in contemporary historiography, is the acronical rising and setting of stars (or planets). Topocentric terms, they provide information about a star's relationship to the Sun and thus its visibility in the sky. Yet there remains ambiguity as to what these two phrases actually mean.

“Acronical” is said to have come from the Greek akros (“point,” “summit,” or “extremity”) and nux (“night”). While all sources agree that the word is originally Greek, there are alternate etymologies for it.

A more serious difficulty with acronical rising and setting is that there are two competing definitions. One I call the Poetical Definition. Acronical rising (or setting) is one of the three Poetical Risings (or Settings) known to classicists. (The other two are cosmical rising/setting, discussed below, and the more familiar helical rising/setting.) The term "poetical" refers to these words use in classical poetry, e. g., that of Columella, Hesiod, Ovid, Pliny the Younger, and Virgil. The Poetical Definition of “acronical” usually is meant in this context.

The Poetical Definition of “acronical” is as follows: When a star rises as the Sun sets, it rises acronically. When a star sets as the Sun sets, it sets acronically.

In contrast with the Poetical Definition, there also is what I call the Astronomical Definition. The Astronomical Definition is somewhat more likely to appear in astronomical, mathematical, or navigational works. When the Astronomical Definition is recorded in dictionaries, it is often with the protasis "In astronomy, ..."

The Astronomical Definition of “acronical” is as follows: When a star rises as the Sun sets, it rises acronically. When a star sets as the Sun rises, it sets acronically.

I will attempt to sort this all out in my talk.

150.02 – **Urania In The Marketplace: Telescopes, Real And Fantastic**

Kenneth S. Rumstay[1]

[1]*Valdosta State University and SARA.*
9:00 AM - 6:30 PM

During the twentieth century astronomical imagery was frequently incorporated, by a variety of industrial manufacturers, into advertisements which appeared in popular magazines. Images of great telescopes, especially, were often invoked to capture the public imagination and to associate a product or service with the noble pursuit of astronomical knowledge. These advertisements fall into three general categories:

1)In many cases the advertiser may have participated directly in the construction or

operation of a new telescope or observatory. That astronomical facility would then be accurately rendered, usually by a photograph, and often identified.

2) In the case of a product or service which had at best a tangential relation to astronomy, a generic telescope or observatory dome might be pictured, with no identification. The intent would be to co-opt the qualities of precision and timeliness, commonly associated with astronomy, for the advertiser's product. In some cases a well-known observatory (most notably the ones atop Mount Wilson and Mount Palomar) would provide a backdrop, thereby linking the manufacturer with a facility in the public eye.

3) In some cases, a service or product might have no astronomical association whatever. Nonetheless, the advertiser might employ an image of a large telescope to invoke a sense of grandeur which would somehow be transferred, in the reader's mind, to that product. In these cases an artist's conception of some fantastic device would often be prepared. In some cases the artist may have had only the vaguest idea of how telescopes were designed, and as a result some remarkably imaginative examples of astronomical engineering graced the pages of our periodicals.

Examples of magazine advertisements from each category, spanning nearly a century, are presented for comparison.

150.03 – **University of Washington's Manastash Ridge Observatory: 40 Years of Astronomy Research and Education**

Julie H. Lutz[1], C. Laws[1], N. Ramien[1]

[1]*Univ. of Washington.*

9:00 AM - 6:30 PM

The University of Washington's Manastash Ridge Observatory (UW MRO) will celebrate the 40th anniversary of its dedication in May 2012. The MRO Boller and Chivens 0.75-m telescope was installed in 1972, following two years of site surveys in the Cascade Mountains east of Seattle. The observatory was used initially for research by UW faculty, as well as for graduate research and training, and during the 1970's and 1980's many of the UW's astronomy PhD theses relied heavily on data obtained at MRO. In recent years MRO has shifted its mission to enabling undergraduate research, and to providing a "capstone" course in advanced photometric methods for our undergraduate majors. Photometry has long been the major source of data from MRO, and the Washington Photometry system for measuring stellar abundances was developed at UW and first deployed at MRO. The cameras at MRO have been used to research a wide variety of objects: cataclysmic variables, RR Lyrae stars, symbiotic stars, novae, X-ray binaries, white dwarfs, M dwarfs, asteroids, comets, star clusters, and many others. Over 100 papers based all or in part upon data obtained at MRO data have appeared in refereed publications. Our poster will present highlights of the research and stories from MRO's history.

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151 – Star Associations, Star Clusters - Galactic & Extra-galactic

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

151.01 – **Filaments of Young Star Clusters and Star Formation in the Outer Regions of NGC 1275**

Jenna E. Ryon[1], R. E. A. Canning[2], J. S. Gallagher[1], R. W. O'Connell[3], A. C. Fabian[2], R. M. Johnstone[2]

[1]*University of Wisconsin - Madison,* [2]*University of Cambridge, United Kingdom,* [3]*University of Virginia.*

9:00 AM - 6:30 PM

We present FUV and optical photometry of star clusters and surrounding diffuse light in the outer regions of NGC 1275, the brightest galaxy in the Perseus Cluster. Observations were taken with the HST/ACS Wide Field Channel and Solar Blind Channel. These spectacular star forming regions extending over tens of kpc resemble those of the giant emission line filaments which are most likely drawn out by rising radio bubbles. Why these star clusters are forming at large projected distances from the main optical body of the galaxy remains a mystery. Ages and masses of the compact star clusters and associated diffuse regions have been found using single stellar population (SSP) modeling of our optical and FUV photometry. Several relevant timescales are compared in an attempt to understand the physical mechanisms that led to this unusual mode of star formation.

This research is based on observations obtained with the NASA/ESA Hubble Space Telescope through program GO-11207 that also supplied partial grant support.

151.02 – **The Size Distributions of Stellar Groupings in Nearby Galaxies: Clues to Formation and Disruption**

Catherine C. Kaleida[1], B. C. Whitmore[2], R. Chandar[3], H. Kim[4]

[1]*Cerro Tololo Inter-American Observatory, Chile,* [2]*The Space Telescope Science Institute,* [3]*University of Toledo,* [4]*Arizona State University.*

9:00 AM - 6:30 PM

We explore the size distribution of star clusters and stellar associations in nearby galaxies, in order to better understand the evolution of stellar clustering in the nearby universe. Using Source Extractor object selection on Gaussian-blurred Hubble Space Telescope (HST) images, we find stellar groupings of sizes ranging from compact clusters (~3 pc) to large stellar associations (~100+ pc). The size of each stellar grouping was measured using the annular surface brightness plotted as a function of radius to determine the total light radius of each object. We also determine the basic properties of these stellar groupings using Spectral Energy Distribution (SED) fitting to Simple Stellar Population (SSP) models (Bruzual & Charlot 2003). Galaxies presented here, NGC 4214, M83, M51, and NGC 2841, are the first set in a larger program in which we will investigate the stellar clustering in a statistically significant sample of ~50 nearby star-forming galaxies. Preliminary results show that the size distributions of nearby galaxies are continuous in nature, indicating that there are no preferred scales for stellar clustering in these galaxies.

This work has been supported by programs HST-AR 1068401A, HST-AR 12137, and HST-AR 11360, 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 NAS5-26555. Analysis of NGC 4214, M83 and NGC 2841 was 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.

151.03 – **Deep Subaru Halpha Observations of M83 XUV Disk**

Jin Koda[1], M. Yagi[2], S. Boissier[3], A. Gil de Paz[4], M. Imanishi[5], J. Donovan Meyer[1], B. F. Madore[6]

[1]*Stony Brook University,* [2]*National Astronomical Observatory of Japan, Japan,* [3]*Laboratoire d'Astrophysique de Marseille, France,* [4]*Departamento de Astrofsica, Universidad Complutense de Madrid, Spain,* [5]*Subaru Telescope, Japan,* [6]*Carnegie Institution of Washington.*

9:00 AM - 6:30 PM

We report Subaru deep Halpha observations of the extended ultraviolet (XUV) disk of M83. Combining Subaru and GALEX data with a stellar population synthesis model, we find that (1) the stochastic stellar initial mass function (IMF) is preferred rather than the truncated IMF, because some low mass stellar clusters (10^2-3Msun) have massive O-type stars; and that (2) the standard Salpeter IMF and a simple aging effect explain the counts of FUV-bright and Halpha-bright clusters. The new data, model, and previous spectroscopic studies provide overall consistent results with respect to the internal dust extinction (AV~0.1 mag) and low metallicity (~0.2Z⊙). After the extinction correction and background subtraction, virtually all clusters in the XUV disk are blue FUV-NUV <0.0 mag.

151.04 – **Dissolution of Young Super Star Clusters in NGC 1569 from Adaptive Optics Imaging**

John-Paul Crawford[1], N. McCrady[1], J. R. Graham[2], W. D. Vacca[3]

[1]*University of Montana,* [2]*University of Toronto, Canada,* [3]*SOFIA-USRA.*

9:00 AM - 6:30 PM

Theory suggests that young massive star clusters (YMCs) are disrupted by numerous dynamical processes and are dissolved into the stellar populations of their host galaxy. The dwarf starburst NGC 1569 contains two of the brightest, most massive young (~ 10 Myr) star clusters within 5 Mpc. Previous studies of the half-light radii of these YMCs have found sizes comparable to the globular clusters in the Milky Way and the LMC. We explore the cluster boundaries by examining the relation between the young cluster stars and the ambient field population. The high spatial resolution of our Keck laser guide star adaptive optics images enables photometry of individual stars down to the confusion limit within 3 pc of the cluster core. We fit isochrones derived from Geneva evolution models to determine the age and extinction of individual stars. Preliminary results indicate the presence of high mass stars with the age of the clusters at radii of 60 to 70 pc, much larger than any nearby globular cluster. These stars act as tracers for the YMC populations, implying that the clusters are observed actively dissolving into the galactic population.

151.05 – **The Panchromatic Hubble Andromeda Treasury: Characterizing Cluster Populations in a Stochastic Regime**

Morgan Fouesneau[1], L. C. Johnson[1], D. R. Weisz[1], A. C. Seth[2], J. J. Dalcanton[1], PHAT Collaboration

[1]*University of Washington,* [2]*University of Utah.*

9:00 AM - 6:30 PM

The Panchromatic Hubble Andromeda Treasury (PHAT) survey provides multi-wavelength coverage of nearly one-third of M31, including thousands of stellar clusters. The sensitivity of HST extends the cluster sample well into the low mass regime, where

stochastic effects of luminous stars can significantly influence the observed integrated light, and must be properly considered when deriving cluster ages and masses.

We have applied a Bayesian analysis technique to account for variations in the integrated cluster light to derive the ages and masses of the ~600 clusters from the Year 1 PHAT observations. Here we present the first results from our characterization of cluster properties, including a comparison with traditional methods of cluster age and mass determination. The large population of low mass clusters in the PHAT sample also provides for best constraints on the cluster mass function outside of the Magellanic Clouds.

151.06 – **The Panchromatic Hubble Andromeda Treasury: A Bayesian Method for Constraining the High Mass Stellar IMF**

Daniel R. Weisz[1], M. Fouesneau[1], D. W. Hogg[2], H. W. Rix[3], J. J. Dalcanton[1], L. C. Johnson[1], PHAT collaboration

[1]*Univ. of Washington,* [2]*New York University,* [3]*MPIA, Germany.*
9:00 AM - 6:30 PM

The high mass stellar initial mass function (IMF) underpins virtually all of extragalactic astrophysics. However, measurements of the IMF above a few solar masses exhibit significant dispersion, and recent evidence is suggestive of environmentally dependent IMF variations. The Panchromatic Hubble Andromeda Treasury (PHAT)program is a multi-wavelength survey including hundreds of resolved young clusters extending from the near-UV to near-IR, allowing for a systematic study of the high mass stellar IMF for a large set of clusters over a wide range of environments.

Here, we present a new Bayesian technique aimed at constraining the properties of the high mass IMF for resolved stars in individual clusters. This method probabilistically considers uncertainties in stellar mass, completeness, and cluster membership, and uses a Markov Chain Monte Carlo (MCMC) to sample the posterior probability distribution. The MCMC analysis allows us to constrain both the slope of the IMF and the upper stellar mass limit for a single cluster, while fully exploring all associated uncertainties and degeneracies. We present simulations that explore the potential biases introduced by the number of observed stars, stellar mass uncertainties, completeness, aging effects and age spread, and binary stars. The application of this technique to the young cluster population in the PHAT survey will result in the one the most comprehensive investigations of the high mass stellar IMF to date. PHAT is supported by HST GO-12055 administered by NASA.

151.07 – **Panchromatic Hubble Andromeda Treasury (PHAT): Comparing Ages and Masses of GALEX UV-Bright Regions and Resolved Stars**

Evan D. Skillman[1], J. Simones[1], D. R. Weisz[2], J. J. Dalcanton[2], B. F. Williams[2], PHAT team

[1]*Univ. of Minnesota,* [2]*Univ. of Washingon.*
9:00 AM - 6:30 PM

The Panchromatic Hubble Andromeda Treasury (PHAT) offers a rich set of multi-wavelength HST imaging (UV through near-IR) with which to study the resolved populations in the disk of M31. This provides a unique opportunity to investigate how well integrated UV flux can be used to estimate various properties (e.g., age, mass, and extinction) of the underlying stellar populations. Kang et al. (2009) measured the total NUV and FUV GALEX flux within a set of UV-bright regions in M31 and used stellar population models to estimate ages and masses. In this followup study, we use a maximum likelihood color-magnitude diagram fitting technique with the optical photometry of resolved stars in the PHAT survey to measure the star formation histories (mass formed as a function of age) within the same UV-bright regions. We compare our results with the ages, masses, and extinction values derived by Kang et al. from integrated UV flux.

Support for this work was provided by NASA through grant GO-12055 from the Space Telescope Science Institute, which is operated by AURA, Inc., under NASA contract NAS5-26555.

151.08 – **PHAT Clusters: Obtaining a Complete View of Stellar Clusters in M31**

Lent C. Johnson[1], A. C. Seth[2], J. J. Dalcanton[1], I. San Roman[3], N. Caldwell[4], M. Fouesneau[1], D. A. Gouliermis[5], P. W. Hodge[1], S. S. Larsen[6], S. Nanda[7], K. A. G. Olsen[8], A. Sarajedini[3], D. R. Weisz[1]

[1]*University of Washington,* [2]*University of Utah,* [3]*University of Florida,* [4]*Harvard-Smithsonian CfA,* [5]*MPIA, Germany,* [6]*University of Utrecht, Netherlands,* [7]*Indian Institute of Technology, Kanpur, India,* [8]*NOAO.*
9:00 AM - 6:30 PM

Using high-resolution, multi-wavelength imaging of M31 from the Panchromatic Hubble Andromeda Treasury (PHAT) multi-cycle program, we have begun to assemble one of the largest and most complete samples of stellar clusters in a disk galaxy to date. We present the Year 1 cluster catalog that includes ~600 high-quality objects, representing the first installment of a ~2500 object sample expected from the full dataset. HST's exquisite resolution and sensitivity has allowed us to identify hundreds of new clusters that push well into the low luminosity regime, down to M(V) ~ -2. We present luminosity functions and structural parameters of the Year 1 clusters, compare our results to previous cluster studies in M31, and highlight interesting science results made possible by this incredible dataset.

151.09 – **An Automated Method for Finding Star Clusters in PHAT**

Knut A. Olsen[1], M. Fouesneau[2], L. Johnson[2], A. C. Seth[3], J. J. Dalcanton[2], D. R. Weisz[2], B. Williams[2]

[1]*NOAO,* [2]*University of Washington,* [3]*University of Utah.*
9:00 AM - 6:30 PM

We describe a method for automatic detection of star clusters in M31, using the multi-band images taken with the Hubble Space Telescope (HST) as part of the Panchromatic Hubble Andromeda Treasury (PHAT). Our method relies on the fact that at the distance of M31, images of star clusters observed with HST contain both a resolved stellar population and a significant amount of unresolved light. First, we use the point source photometry generated as part of the PHAT pipeline to subtract point sources from the images, leaving behind only the unresolved light, in addition to image artifacts. Next, we use the filtered, subtracted images to identify peaks in unresolved light. We compare these peaks to the point source photometric catalog to remove some of the contaminants and to identify likely candidate clusters. Finally, we employ neural network techniques to remove additional contaminants. Tests of the method show that we can automatically identify 85-90% of star clusters identified through by-eye searches, as well as find additional possible star clusters not found by eye. Implementation of this method will allow for the quantitative measurement of star cluster detection probability and completeness in the PHAT data, something which will be otherwise difficult to accomplish with by-eye searches.

151.10 – **PHAT Clusters: Constraining the Properties of Partially Resolved Clusters**

Lori Beerman[1], L. C. Johnson[1], D. R. Weisz[1], J. J. Dalcanton[1], PHAT Collaboration

[1]*University of Washington.*
9:00 AM - 6:30 PM

Traditionally, the light from young stellar clusters has been studied in one of two ways: as an ensemble of individual resolved stars, or as a single integrated value when stars cannot be individually resolved. However, the increasing spatial sensitivity of observations often results in a third possibility where we resolve a handful of a cluster's luminous stars, but the remainder of the cluster's light remains unresolved. Especially in the case of low mass clusters, the contribution from these few bright resolved stars can strongly influence the observed colors of a cluster, thus making it difficult to accurately derive cluster properties such as age, mass, and extinction strictly from the total integrated light. Here, we present a new technique for determining the characteristics of partially resolved clusters by excluding the bright resolved stars, utilizing the stability of the remaining, unresolved light component. We demonstrate the capabilities of this technique by comparison to a variety of simulations. Furthermore, we apply this new technique to a set of partially resolved clusters observed as part of the Panchromatic Hubble Andromeda Treasury (PHAT) program, and compare our derived cluster properties with those obtained from traditional methods.

151.11 – **HST CMDs of M31 Massive Clusters in the PHAT Survey**

Nelson Caldwell[1], A. Dolphin[2], B. Williams[3], A. Seth[4], PHAT team

[1]*Center for Astrophysics,* [2]*Raytheon,* [3]*UWa,* [4]*UUtah.*
9:00 AM - 6:30 PM

Multicolor stellar photometry of HST data collected as part of the PHAT project has been performed using the DOLPHOT suite of programs. We present color-magnitude diagrams created in F475W and F814W (BI) of several massive, old clusters, and compare the metallicities derived from the color of the giant branch stars with that derived from integrated light spectroscopy. As well, we compare the ages of massive, young clusters with those found from spectra.

151.12 – **Spectra Of Star Clusters In The Large Magellanic Cloud As An Age Indicator**

Randa Asa'd[1], M. M. Hanson[1], A. Ahumada[2]

[1]*University of Cincinnati,* [2]*European Southern Observatory, Chile.*
9:00 AM - 6:30 PM

In a recent study of 84 LMC stellar clusters, we showed there is only a weak correlation between the CMD age and the age assigned by means of their integrated photometry alone (Asa'd & Hanson, 2011). We seek to determine if integrated spectra alone can provide better age estimations of unresolved clusters. To investigate this, we are obtaining integrated spectra for our sample of 84 LMC clusters with CMD ages, and will present preliminary results for 7 clusters observed with the 4m Blanco Telescope (Chile) in the visible. We derive information about the age and the extinction of these clusters using the equivalent width of the Balmer lines, comparing the clusters' spectra with template spectra of star clusters with known parameters, and comparing the spectra with computational models. We will continue to obtain integrated spectra for all 84 clusters from our original study to investigate if spectra can provide more accurate

age estimates than integrated photometry.

151.13 – **Hunting for Shooting Stars in 30 Doradus**

Selma E. de Mink[1], D. J. Lennon[1], E. Sabbi[1], J. Anderson[1], L. R. Bedin[2], S. Sohn[1], R. P. van der Marel[1], N. R. Walborn[1], N. Bastian[3], E. Bressert[4], P. A. Crowther[5], C. J. Evans[6], A. Herrero[7], N. Langer[8], H. Sana[9]

[1]*Space Telescope Science Institute,* [2]*Osservatorio Astronomico di Padova, Italy,* [3]*Universitats-Sternwarte Munchen, Germany,* [4]*European Southern Observatory, Germany,* [5]*University of Sheffield, United Kingdom,* [6]*Royal Observatory Edinburgh, United Kingdom,* [7]*Instituto de Astrofisica de Canarias, Spain,* [8]*Universitat Bonn, Argelander Institute for Astronomy, Germany,* [9]*Universiteit van Amsterdam, Netherlands.*

9:00 AM - 6:30 PM

We are undertaking an ambitious proper motion survey of massive stars in the 30 Doradus region of the Large Magellanic Cloud using the unique capabilities of HST. We aim to derive the directions of motion of massive runaway stars, searching in particular for stars which have been ejected from the dense star cluster R136.

These stars probe the dynamical processes in the core of the cluster. The core has been suggested as a formation site for very massive stars exceeding the canonical upper limit of the IMF. These are possible progenitors of intermediate-mass black holes. Furthermore, they provide insight about the origin of massive field stars, addressing open questions related to the poorly understood process of massive star formation. Some may originate from disrupted binary systems and bear the imprints of interaction with the original companion. They will end their life far away from their birth location as core collapse supernova or possibly even long gamma-ray bursts.

Here we discuss the first epoch of observations, presenting a 16'x13' mosaic of the data, and initial results based on comparisons with archival data.

SdM acknowledges the NASA Hubble Fellowship grant HST-HF-51270.01-A awarded by STScI, operated by AURA for NASA, contract NAS 5-26555.

151.14 – **Comparing Age and Mass Determinations from 100 Million Monte Carlo Simulations to 288 LMC Clusters with CMD Ages**

Bogdan Popescu[1], M. M. Hanson[1]

[1]*Univ of Cincinnati.*

9:00 AM - 6:30 PM

Traditional Simple Star Population (SSP) models compute the integrated colors of stellar clusters in the *infinite mass limit,* where colors are independent of mass and the stellar mass function is fully populated. However, real clusters have a finite mass and an insufficient number of stars to fully populate the mass function, particularly among the high mass stars. Our MASSCLEAN SSP models offer a more realistic representation, as they provide mass-dependent integrated colors and include the effect of stochastic fluctuations for finite mass clusters. We've completed 100 million Monte Carlo simulations to create a database revealing the dispersion of integrated colors observed in LMC-like clusters. Our MASSCLEAN*age* application uses this database with the observed integrated photometry of LMC clusters to solve, simultaneously, for mass and age. Our MASSCLEAN ages compare very well to CMD ages found for the 288 LMC clusters studied, far better than methods using χ^2 minimization fit to traditional SSP models in the *infinite mass limit*. We find the χ^2 minimization method will produce an excess of very young and old clusters, and a deficit of clusters in the *log(age/yr)*= [7.0,7.5] range, as compared to CMD ages. While the age of massive clusters with colors close to the *infinite mass limit* are often estimated well by the traditional method, the sometimes very red and often low mass clusters can lead to many catastrophic errors in age determination. Integrated colors are the only available measurement for age and mass determination for unresolved or partially resolved stellar clusters in The Local Group and beyond. Cluster age and mass are used to estimate a whole range of properties for populations of clusters and galaxies, making accurate values crucial to a broad number of investigations. This material is based upon work supported by the National Science Foundation under Grant No. 0607497 & 1009550.

151.15 – **Dynamics of Globular Clusters with Multiple Stellar Populations: Binary Star Disruption**

Enrico Vesperini[1], S. L. W. McMillan[1], F. D'Antona[2], A. D'Ercole[3]

[1]*Drexel Univ.,* [2]*INAF-Osservatorio Astronomico di Roma, Italy,* [3]*INAF-Osservatorio Astronomico di Bologna, Italy.*

9:00 AM - 6:30 PM

A number spectroscopic and photometric studies have provided strong evidence of the presence of multiple stellar populations in globular clusters and raised many fundamental questions concerning the formation and dynamical history of these systems. In a previous investigation aimed at exploring the formation of second-generation (SG) stars from the ejecta of first-generation (FG) asymptotic giant branch stars, and the subsequent dynamical evolution of the cluster, we showed that SG stars are expected to form in a dense subsystem concentrated in the inner regions of the FG cluster. Here we present the results of a study aimed at exploring the long-term dynamical evolution of multiple-population clusters and the implications of the presence of the inner SG subsystem for the disruption of binary stars. We quantify the enhancement of the binary disruption rate due to the presence of the central SG subsystem for a number of different initial conditions. Our calculations show that SG binaries,which are assumed to be more concentrated in the cluster inner regions, are disrupted at a substantially larger rate than FG binaries. Assuming a similar initial fraction of FG and SG binaries,our dynamical study indicates that the SG population is now expected to contain a significantly smaller binary fraction than the FG population.

151.16 – **Structure and Dynamics of the Globular Cluster Palomar 13**

Jeremy Bradford[1], M. Geha[2], R. R. Munoz[3], F. A. Santana[3], J. D. Simon[4], P. Cote[5], P. B. Stetson[5], E. Kirby[6], S. G. Djorgovski[6]

[1]*Yale University, Central Connecticut State University,* [2]*Yale University,* [3]*Universidad de Chile, Chile,* [4]*The Observatories of the Carnegie Institution of Washington,* [5]*National Research Council of Canada, Herzberg Institute of Astrophysics, Canada,* [6]*California Institute of Technology.*

9:00 AM - 6:30 PM

We present Keck/DEIMOS spectroscopy and CFHT/MegaCam photometry for the Milky Way globular cluster Palomar 13. We triple the number of spectroscopically confirmed members, including many repeat velocity measurements. Palomar 13 is the only known globular cluster with possible evidence for dark matter, based on a Keck/HIRES 21 star velocity dispersion of σ=2.2+/-0.4 km/s. We reproduce this measurement, but demonstrate that it is inflated by unresolved binary stars. For our sample of 61 stars, the velocity dispersion is σ=0.7(+0.6/-0.5) km/s. Combining our DEIMOS data with literature values, our final velocity dispersion is σ=0.4(+0.4/-0.3) km/s. We determine a spectroscopic metallicity of [Fe/H]=-1.6+/-0.1 dex, placing a 1-σ upper limit of σ[Fe/H]~0.2 dex on any internal metallicity spread. We determine Palomar 13's total luminosity to be M_V=-2.8+/-0.4, making it among the least luminous known globular clusters. The photometric isophotes are regular out to the half-light radius and mildly irregular outside this radius. The outer surface brightness profile slope is shallower than typical globular clusters (η=-2.8+/-0.3). Thus at large radius, tidal debris is likely affecting the appearance of Palomar 13. Combining our luminosity with the intrinsic velocity dispersion, we find a dynamical mass of of $M_{1/2}$=1.3(+2.7/-1.3)x10^3 M_{sun} and a mass-to-light ratio of M/L_V=2.4(+5.0/-2.4) M_{sun}/L_{sun}. Within our measurement errors, the mass-to-light ratio agrees with the theoretical predictions for a single stellar population. We conclude that, while there is some evidence for tidal stripping at large radius, the dynamical mass of Palomar 13 is consistent with its stellar mass and neither significant dark matter, nor extreme tidal heating, is required to explain the cluster dynamics.

151.17 – **New BVI Photometry of Pal 13**

Nathaniel Paust[1], R. Nevin[1], B. Chaboyer[2]

[1]*Whitman College,* [2]*Dartmouth College.*

9:00 AM - 6:30 PM

We present new wide-field BVI photometry of the Galactic globular cluster Palomar 13. The photometry covers a radius of approximately 10 arcminutes from the cluster center and ranges from the tip of the red giant branch to below the main sequence turnoff. We use this photometry to measure the cluster's age and distance and derive structural parameters for the cluster.

151.18 – **Distribution of Lick Indices in the Globular Cluster NGC 2808**

Julia O'Connell[1]

[1]*Tennessee State University.*

9:00 AM - 6:30 PM

We have analyzed low resolution spectra for a large sample (~200) of red giant branch (RGB) stars in the Galactic globular cluster NGC 2808 for indications of bimodality with respect to Lick indices and radial dispersion. Target stars were observed in nine fields over 5 nights in March 2010 with the Blanco 4m telescope and Hydra multi--object positioner and bench spectrograph located at Cerro Tololo Inter--American Observatory. The full wavelength coverage spans from ~3900--8200 A; for nights 1 and 2, and from ~4500--6950 A; for nights 3, 4, and 5. The low resolution data (<R>~500 for nights 1 and 2,<R>~1200 for nights 3, 4, and 5; <S/N>~70) were used to measure radial velocities (RVs) and to determine cluster membership. RVs were measured with the IRAF task *xcsao* using stars with known radial RVs included in our observed fields as templates. Template candidates were taken from Cacciari et al. (2004) and Carretta et al. (2006), and cross--matched by RA and Dec to stars in our sample. A conservative approach was adopted when including stars as cluster members, with RV= 101.9 ± 7.17 km s^{-1} (σ=2.83). *Indexf* was employed to measure 12 Lick indices, with particular attention to CN1, CN2 and Na. The peak distribution of these indices appears to be correlated in stars ~2.5--3.5 arc minutes from the cluster center. The correlation becomes less apparent in stars outside this radius.

151.19 – **Discovery of 6 SX Phoenicis Stars in the Globular Cluster NGC 4833**

Brian W. Murphy[1], A. N. Darragh[1]

[1]*Butler University & SARA Observatory.*
9:00 AM - 6:30 PM

We report the discovery of 6 SX Phoenicis stars in the globular cluster NGC 4833. Images were obtained from January through June 2011 with the Southeastern Association for Research in Astronomy (SARA) 0.6 meter telescope located at Cerro Tololo Interamerican Observatory. The image subtraction method of Alard & Lupton (1998) was used to search for variable stars in the cluster. We confirmed 16 previously known variables cataloged by Demers & Wehlau (1977). In addition to the previously known variables we have identified 11 new variables. Of the total number of confirmed variables in our 10x10 arc minute field, we classified 10 RRab variables, with a mean period of 0.69591 days, 9 RRc, with a mean period of 0.39555 days, a W Ursae Majoris contact binary, an Algol-type binary, and the 6 SX Phoenicis stars with a mean period of 0.05847 days. The periods and relative numbers of RRab and RRc variables are indicative of the cluster being of the Oosterhoff type II. We present the periods of previously known variables and the periods, classification, and multi-color light curves of the newly discovered variables, and their location on the color-magnitude diagram. This project was funded in part by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004 872 and by a grant from the Butler Institute for Research and Scholarship.

151.20 – **Discovery of 27 New Variable Stars in the Globular Cluster NGC 6584**

Joseph Toddy[1], E. W. Johnson[2], A. N. Darragh[2], B. W. Murphy[2]

[1]*University of Georgia,* [2]*Butler University.*
9:00 AM - 6:30 PM

Using the Southeastern Association for Research in Astronomy 0.6 meter telescope located at Cerro Tololo, we searched for variable stars in the globular cluster NGC 6584. We obtained images for 10 nights between 28 May and 6 July of 2011. After processing the images, we used the image subtraction technique developed by Alard (2000) to search for the variable stars. We detected a total of 69 variable stars in our 10x10 arc-minute field, including 42 previously known variables cataloged by Millis & Liller (1980) and 27 hereto undetected variables. In total, we classified 44 as type RRab, with a mean period of 0.56776 days, 16 as type RRc with a mean period of 0.30886 days, 6 eclipsing binaries, and 3 long period (P > 2 days) variable stars. Many of the RR Lyrae stars exhibited the Blazhko Effect. Furthermore, the RR Lyrae stars exhibit a period/amplitude relationship consistent with NGC 6584 being an Oosterhoff Type I cluster. Here we present refined periods, complete multi-color light curves, and classifications for each of the 69 variables, as well Oosterhoff and color-magnitude diagrams for the cluster. This project was funded in part by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004 872 and by a grant from the Butler Institute for Research and Scholarship.

151.21 – **Revealing New Open Clusters with the GLIMPSE-360 Survey**

Karen Hamm[1], R. L. Beaton[1], G. Zasowski[1], S. R. Majewski[1], B. A. Whitney[2]

[1]*University of Virginia,* [2]*University of Wisconsin.*
9:00 AM - 6:30 PM

We identify and investigate new and poorly studied open clusters in the recently obtained GLIMPSE-360 data. After identifying the clusters and candidates visually in the GLIMPSE survey images, we dereddened the 2MASS color-magnitude diagrams (CMDs) using the RJCE method and performed isochrone fitting. We identified 22 candidates with convincing cluster CMDs and no existing identification in the literature, and we obtained follow-up photometry for a few selected candidates. The purpose of this project is to determine the basic parameters (age, reddening, metallicity and distance) of these open clusters where possible, thus contributing to the ongoing census of open clusters in the Milky Way.

151.22 – **Comparison of Padova and Dartmouth Isochrones Using Deep Near Infrared Data for Key Open Clusters.**

Benjamin Thompson[1], P. Frinchaboy[1], T. Irwin[2], J. Kalirai[3]

[1]*Texas Christian University,* [2]*Texas A&M,* [3]*STSCI.*
9:00 AM - 6:30 PM

We present a comparison of results from using Padova and Dartmouth isochrones for several open clusters (M35, NGC 2158, M37, M67) in the infrared. Using newly reduced deep near infrared data (J ~ 20), we compare the validity of these isochrones at low mass, and over a wide range in cluster ages. In addition, we combine the new deep NIR data with 2MASS, mid infrared photometry (3.0-8.0 micron) and optical (UBVRI) data to construct a wide photometric set for each cluster. We look for variations in isochrone-derived parameters when using different color-magnitude combinations.

151.23 – **A Hubble Space Telescope Photometric Study of the Galactic Open Cluster Westerlund 2**

Carlos Vargas Alvarez[1], H. Kobulnicky[1]

[1]*University of Wyoming.*
9:00 AM - 6:30 PM

The young and massive Galactic open cluster Westerlund 2 has been a source of controversy because of the widely varying and inconsistent estimates for its distance. In this study we use *Hubble Space Telescope* multi-band photometry to make improved photometric measurements in the crowded cluster core where many of the most luminous members are now resolved into multiple stars. Using new stellar spectroscopy, we provide a more reliable distance measurement based on the mean spectroscopic parallax of ~20 O-type member stars. The new spectrophotometric distance, after correction for reddening, is 7.38 ± 0.02 (random) ± 0.08 (systematic) kpc. We also use the *HST* optical photometry along with mid-infrared photometry to correct for reddening on a star-by-star basis. Differential reddening causes A_V to vary from 1.11 mag to as much as 39.25 mag across the cluster. The best solar metallicity isochrone fit to the de-reddened color-magnitude diagram corresponds to an age of 1 - 3 Myr.

151.24 – **A Comprehensive Story Of Young Star Cluster NGC 3603**

Xiaoying Pang[1], E. K. Grebel[1], A. Pasquali[1], M. Altmann[1], R. Allison[1]

[1]*Heidelberg University, Germany, Germany.*
9:00 AM - 6:30 PM

We study the young massive (10^4 solar mass) star cluster NGC 3603 in the Galaxy with HST deep photometry. The membership of stars is determined by relative proper motions based on two epoch WFPC2 data. The radially varying mass function of the members shows significant mass segregation ranging from slopes of Gamma=-0.26±0.32 in the inner 5" to Gamma=-1.49±0.33 in the outermost annulus (15"--20"). The mass segregation is confirmed using the minimum spanning tree technique, which reveals mass segregation down to 5 solar masses. Both analyses show that the mass segregation in NGC 3603 is dependent on stellar mass, such that more massive stars tend to be more mass-segregated than their lower-mass counterparts. Despite the young age (1 Myr) for the main-sequence (MS) stars, we find a possible age spread of up to 3 Myr for pre-main-sequence (PMS) stars in the core and an even larger age spread up to 30 Myr among the PMS stars in the outskirts of the cluster. Since the outer part of NGC 3603 is dominated by molecular clouds, we computed the pixel-to-pixel distribution of the color excess, E(B - V)g, of the gas associated with this cluster from its Halpha/Paschenβ flux ratio using WFC3 images. At the assumed distance of 6.9 kpc, the resulting median color excess within 1 pc from the cluster center is E(B - V)g=1.51 ± 0.04 mag. Outside the cluster (at r > 1 pc), the color excess is seen to increase with cluster-centric distance toward both north and south, reaching a value of about 2.2 mag at r=2 pc from the cluster center. We are currently establishing a conversion from gas to stellar reddening, aiming at correcting individual MS and PMS stars for reddening in the WFC3 field of view and achieve an accurate age determination of the cluster.

151.25 – **A New Look At An Old Cluster: Age, Activity, And Rotation In NGC 752**

Emily C. Bowsher[1], M. Agüeros[1], J. Bochanski[2], P. Cargile[3], K. Covey[4], A. Kraus[5], N. Law[6], K. Stassun[3]

[1]*Columbia University,* [2]*Pennsylvania State University,* [3]*Vanderbilt University,* [4]*Lowell Observatory,* [5]*Institute for Astronomy, University of Hawaii,* [6]*Dunlap Institute, University of Toronto, Canada.*
9:00 AM - 6:30 PM

Large uncertainties exist in our understanding of how stellar rotation and activity in Sun-like stars evolves after they reach the age of the Hyades, roughly 0.5 Gyr. Rotation periods are scarce for older stars, seriously complicating the calibration of an age-rotation-activity relation one can apply to field stars. The Palomar Transient Factory (PTF) survey of open clusters is an effort to map stellar rotation in nearby open clusters of different ages. We provide an update on our ongoing work on NGC 752, a 1-2 Gyr open cluster at a distance of only ~450pc. We have completed a season of R-band PTF observations of two overlapping fields centered on the cluster. These observations spanned five months, included ~400 separate epochs for each field, and produced over 50,000 light curves per field. Our preliminary results include updated membership information based on radial velocity measurements made from MDM and WIYN/Hydra spectra, an improved cluster age estimate based on isochrone fitting, and a sample of newly identified variable and periodic stars. As the closest known intermediate-age cluster, NGC 752 represents one of the best opportunities we have to study the age-rotation-activity relation in main sequence stars at ages near 1 Gyr.

151.26 – **Ruprecht 147: Membership and Properties of the Nearest Old Cluster**

Jason L. Curtis[1], J. T. Wright[1]

[1]*The Pennsylvania State University.*
9:00 AM - 6:30 PM

Ruprecht 147 is a hitherto unappreciated open cluster that holds great promise as a standard in fundamental stellar astrophysics. Past attempts at characterization have been hindered by a limited (and in one case, a completely erroneous) membership list and poor photometry. We are amidst a multi-telescope campaign to characterize R147,

catalog its members, and prove its benchmark status. We have conducted a radial velocity survey of astrometric candidates with Lick, Palomar, and MMT/Hectochelle and identify over 100 high-confidence members, including 5 blue stragglers, 11 red giants, and 4 SB2 binaries. We are in the process of determining the cluster metallicity from an SME analysis of three Keck/HIRES spectra (initial result indicates near-Solar metallicity). We have obtained deep CFHT/MegaCam g'r'i'z' photometry and fit Padova isochrones using the tau-squared maximum-likelihood procedure of Naylor et al. (2009). While uncertainty remains due to the unresolved binary population and likelihood of differential extinction across this large cluster, we find R147 to be approximately at 250 pc and 2.8 Gyr, making it the closest old cluster by a factor of 2 in each dimension. We intend to submit for publication our membership list and initial results prior to AAS.

151.27 – **Core Collapse: The Race Between Stellar Evolution and Binary Heating**

Joseph M. Converse[1], R. Chandar[1]

[1]*University of Toledo.*

9:00 AM - 6:30 PM

The dynamical formation of binary stars can dramatically affect the evolution of their host star clusters. In relatively small clusters (M < 6000 Msun) the most massive stars rapidly form binaries, heating the cluster and preventing any significant contraction of the core. The situation in much larger globular clusters (M ~ 10^5 Msun) is quite different, with many showing collapsed cores, implying that binary formation did not affect them as severely as lower mass clusters. More massive clusters, however, should take longer to form their binaries, allowing stellar evolution more time to prevent the heating by causing the larger stars to die off. Here, we simulate the evolution of clusters between those of open and globular clusters in order to find at what size a star cluster is able to experience true core collapse. Our simulations make use of a new GPU-based computing cluster recently purchased at the University of Toledo. We also present some benchmarks of this new computational resource.

151.28 – **The Dynamical Formation of Young Black Hole Binaries in Dense Star Clusters**

Kristen Garofali[1], J. Converse[2], R. Chandar[2], B. Rangelov[2]

[1]*Michigan State University,* [2]*University of Toledo.*

9:00 AM - 6:30 PM

Observations of the nearby starburst galaxy NGC 4449 taken with the Chandra and Hubble Space Telescopes have led to the discovery of a population of very young (< 10 Myr), massive black-hole x-ray binaries located within or close to star clusters. We ran a suite of N-body simulations to determine whether these very young black-hole binaries could have formed purely through dynamical interactions in the dense cluster cores. Our simulated clusters all contain N=16,384 stars, and span a large range of initial sizes and density profiles, both with and without primordial mass segregation. These parameters cover clusters with properties similar to those of the x-ray binary hosts in NGC 4449, but also include more extreme stellar systems. Our main result is that x-ray binary candidates are only produced by such a young age in clusters with unrealistic initial conditions. Hence, the very young, black-hole x-ray binaries in NGC 4449 cannot have formed dynamically, but must have been present from the clusters' birth.

151.29 – **Age Determination for the Open Cluster NGC 6939 from the Eclipsing Binary V12**

Chantal Gonzalez[1], E. L. Sandquist[1], E. George[2], M. Shetrone[3], J. Orosz[1]

[1]*San Diego State University,* [2]*Humboldt State University,* [3]*McDonald Observatory.*

9:00 AM - 6:30 PM

Measuring precise ages in astronomy is a very difficult task, but star clusters often provide the best opportunities to make age determinations. Eclipsing binary systems in star clusters can produce high-precision measurements of the masses and radii of the two orbiting stars, and an eclipsing binary close to the cluster turnoff can lead to a precise age. We performed a study of the totally-eclipsing binary star V12 in the (~1.0-1.6 Gyr) open star cluster NGC 6939 using photometry from the Mount Laguna Observatory 1 meter telescope and radial velocities using the 9-meter Hobby-Eberly Telescope. We will present precise masses and radii for the stars, and a new determination of the age of the cluster.

We gratefully acknowledge funding from the National Science Foundation under grant AST-0908536 and support of E.G. through grant AST-0850564 as part of the CSUURE Research Experiences for Undergraduates (REU) Program at San Diego State University.

151.30 – **The AB Dor Moving Group: A Chemically Heterogeneous Kinematic Stream?**

Scott A. Barenfeld[1], E. J. Bubar[2], E. E. Mamajek[1], P. A. Young[3]

[1]*University of Rochester,* [2]*Marymount University,* [3]*Arizona State University.*

9:00 AM - 6:30 PM

The AB Dor Moving Group is the nearest kinematic group to the Sun. It consists of a "nucleus" of ~10 comoving stars at distance ~20 pc (Zuckerman et al. 2004), along with dozens of purported "stream" members spread out across the sky, with distances up to 140 pc away (Torres et al. 2008). We perform a kinematic and chemical analysis of a sample of 10 AB Dor "stream" members to test whether they constitute a physical stellar group. We use the NEMO Galactic kinematic code to investigate the orbits of the stream members, and perform a chemical abundance analysis using high resolution, high S/N spectra taken with the MIKE spectrograph on the Magellan Clay 6.5-m telescope. Using a chi-squared test with the measured abundances for 10 different elements (Fe, Na, Mg, Si, Al, Ca, Cr, Mn, Ni, and Ba), we find that only a few of the ten purported AB Dor stream members appear to constitute a statistically chemically homogeneous sample. Our orbit simulations show that some of the "stream" members were hundreds of pc from AB Dor ~100 Myr ago, and hence were unlikely to have formed near the eponymous star. The lack of kinematic and chemical coherence among the stream sample suggests that the published lists of AB Dor moving group members are unlikely to represent the dispersed remnant of a single star formation episode. Our study does not rule out the physicality of the AB Dor "nucleus" identified by Zuckerman et al., which appears to be coeval with the Pleiades (~120 Myr). We conclude that the AB Dor stream is dynamical in nature, likely containing stars from many different birth sites.

This research was supported by NSF grant AST-1008908, an REU supplement, and funds from the School of Arts and Sciences at the University of Rochester.

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152 – Stellar Evolution, Stellar Populations, Abundances

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

152.01 – **The Circumstellar Environment of R Coronae Borealis: White Dwarf Merger or Final Helium Shell Flash?**

Geoffrey C. Clayton[1]

[1]*Louisiana State Univ..*

9:00 AM - 6:30 PM

In 2007, R Coronae Borealis (R CrB) went into an historically deep and long decline. In this state, the dust acts like a natural coronograph at visible wavelengths, allowing faint nebulosity around the star to be seen. Several of the structures around R CrB are cometary globules caused by wind from the star streaming past dense blobs. The estimated dust mass of the knots is consistent with their being responsible for the R CrB declines if they form along the line of sight to the star. In addition, there is a large diffuse shell extending up to 4 pc away from the star containing cool 25 K dust that is detected all the way out to 500 μm. The evidence pointing toward a white-dwarf merger or a final-helium-shell flash origin for R CrB is contradictory. The shell and the cometary knots are consistent with a fossil planetary nebula. Along with the fact that R CrB shows significant Lithium in its atmosphere, this supports the final-helium-shell flash. However, the relatively high inferred mass of R CrB and its high fluorine abundance support a white-dwarf merger.

152.02 – **Mass Loss and Stellar Evolution Models of Polaris**

Hilding R. Neilson[1], S. G. Engle[2], E. Guinan[2], N. Langer[1]

[1]*University of Bonn, Germany,* [2]*Villanova University.*

9:00 AM - 6:30 PM

Polaris is a first-overtone Cepheid with a measured rate of period change that probes real-time evolution of that star. In this work, we compare the measured period change with rates computed from a grid of state-of-the-art stellar evolution models that are consistent with the effective temperature, luminosity and mass of Polaris. We find that the theoretical and measured rates of period change do not agree, and we show this difference implies that Polaris is losing mass at a rate of 10^{-6} solar masses per year.

152.03 – **Manganese Abundances In Three Metal-poor Stars Using Improved log(gf) Data For Mn I And Mn II Lines**

James E. Lawler[1], J. S. Sobeck[2], E. A. Den Hartog[1], C. Sneden[3], J. J. Cowan[4], J. W. Truran[2]

[1]*University of Wisconsin,* [2]*University of Chicago,* [3]*University of Texas,* [4]*University of Oklahoma.*

9:00 AM - 6:30 PM

We present accurate Mn abundances for three very metal-poor stars using new log(gf) measurements [Den Hartog et al. 2011] for transitions of Mn I and Mn II spanning a wavelength range from 2300 to 6050 Å. The three metal-poor ([Fe/H] < -2.0) program stars are HD 84937 (a warm main sequence turn-off star), HD 122563 (a cool giant deficient in n-capture elements) and HD115444 (a cool giant with extreme enhancements of n-capture elements). Using approximately 20 transitions of Mn I and more than 10 transitions of Mn II we find for each star a highly consistent abundance

value, log ε(Mn) = 2.9 for HD 84937, log ε(Mn) = 1.6 for HD 115444, and log ε(Mn) = 1.9 for HD 122563, except for the resonance (E.P. = 0.0) multiplet of Mn I. This multiplet consistently yields lower abundance values with differences ranging from ~0.3 dex for HD 84937 (a main sequence star) to ~ 0.7 and 0.9 dex for the giant stars included in the study. We have critically examined aspects of radiative transfer for each of the Mn I and II transitions including depth of formation. Using estimates of the Fe abundances for these three well-studied metal-poor stars, we conclude that [Mn/Fe] = -0.70 ± 0.2 in the metalicity regime [Fe/H] = -2.5 ± 0.3.

Supported by NASA grant NNX09AL13G and NSF grants AST-0907732, AST-0908978, and AST-0707447.

Den Hartog, E A, Lawler J E, Sobeck J S, Sneden C, and Cowan J J 2011, ApJS 194, 35

152.04 – **Improved Yttrium and Zirconium Abundances in Metal-Poor Stars**

Renata Violante[1], E. Biemont[2], J. J. Cowan[3], C. Sneden[1]

[1]*University of Texas,* [2]*Université de Mons, Belgium,* [3]*University of Oklahoma.*
9:00 AM - 6:30 PM

Abstract

We present new abundances of the lighter *n*-capture elements, Yttrium (Z=39) and Zirconium (Z=40) in the very metal poor, *r*-process rich stars BD+17 3248 and HD 221170. Very accurate abundances were obtained by use of the new transition probabilities for Y II published by *Biémont et al. 2011*, and Zr II by *Malcheva et al. 2006*, and by expanding the number of transitions employed for each element. For example, in BD+17 3248, we find *log επσιλον*=-0.03 +/- 0.03 (σιγμα=0.15, from 23 lines) for Y II. As for Zr II, *log επσιλον* = 0.65 +/- 0.03 (σιγμα = 0.1, from 13 lines). The resulting abundance ratio is *log επσιλον* [Y/Zr] = -0.68 +/- 0.05. The results for HD 221170 are in accord with those of BD+17 3248. The quantity of lines used to form the abundance means has increased significantly since the original studies of these stars, resulting in more trustworthy abundances. These observed abundance ratios are in agreement with an *r-process*-only value predicted from stellar models, but is under-abundant compared to an empirical model derived from direct analyses of meteoritic material. This ambiguity should stimulate further nucleosynthetic analysis to explain this abundance ratio.

We would like to extend our gratitude to NSF grant AST-0908978 and the University of Texas Astronomy Department Rex G. Baker, Jr. Endowment for their financial support in this project.

152.05 – **Galactic Globular Cluster NGC1261: "Young", Low-alpha and Star-to-Star Abundance Variations In Na-O?**

Dan Filler[1], I. I. Ivans[1], J. Simmerer[1]

[1]*The University of Utah.*
9:00 AM - 6:30 PM

We present the first high-resolution (R~40,000) chemical abundance analysis of the relatively young (8-9 Gyr), outer halo Galactic globular cluster NGC 1261. Stellar parameters for three stars were derived using spectroscopic constraints. Abundances were deduced using a combination of EWs and fitting synthetic spectra. Our derived metallicity ([Fe/H] = -1.19 ± 0.02) is in excellent agreement with the metallicity scale of Kraft & Ivans (2003, 2004). However, the Na-O anticorrelation spanning 1.1 ± 0.1 dex in sodium, is as large as any other cluster reported to date. In the light element group, we report -0.9 < [C/Fe] < -0.6 with C12/C13 = 4, (for which three regions in the G-band were synthesized); +0.5 < [N/Fe] < +1.1 from the CN band head near 8004A; -0.25 < [O/Fe] < +0.2 from the forbidden lines; -0.3 < [Al/Fe] < +0.15 from the aluminum doublet near 6696A. We also present abundances for the alpha-elements [Mg/Fe] = +0.2 ± 0.1; [Si/Fe] = +0.1 ± 0.1; [Ca/Fe] = +0.15 ± 0.1; [Ti/Fe] = +0.15 ± 0.15. NGC 1261 is distinguished from other clusters of comparable metallicity due to low-alpha abundances. We will discuss the nucleosynthetic histories that may have given rise to these abundances including the possibility of enrichment by Type 1a supernovae. We also report abundances for the iron-peak elements [Sc/Fe] = +0.0 ± 0.2; [V/Fe] = -0.1 ± 0.1; [Cr/Fe] = -0.1 ± 0.15; [Mn/Fe] = -0.1 ± 0.15; [Co/Fe] = +0.2 ± 0.1; [Ni/Fe] = +0.0 ± 0.1; the light neutron-capture elements [Y/Fe] = +0.1 ± 0.1; [Zr/Fe] = +0.35 ± 0.1; the s-process elements [Ba/Fe] = +0.15 ± 0.1; [La/Fe] = +0.1 ± 0.1; [Nd/Fe] = +0.15 ± 0.1; and the r-process element [Eu/Fe] = 0.6 ± 0.2.

152.06 – **Kinematic Analysis of Subpopulations in NGC 1851 and NGC 2808**

Katharine Larson[1], N. Byler[2], A. Seth[1], M. Walker[3], M. Mateo[4], J. Strader[3]

[1]*University of Utah,* [2]*University of Washington,* [3]*Harvard-Smithsonian CfA,* [4]*University of Michigan.*
9:00 AM - 6:30 PM

We investigate the kinematics of two massive nearby globular clusters, NGC 1851 and NGC 2808. These clusters were chosen because existing abundance and CMD measurements provide strong evidence for multiple generations of star formation. We obtained high-resolution spectra of >1000 cluster member stars in the Mg triplet portion of the spectrum using the Magellan/MIKE fiber system. From the spectra, we extract radial velocities and relative Mg abundances to perform chemical and kinematic analyses in each cluster. Based on observed spreads in the abundances, we divide each cluster into Mg-poor and Mg-rich subpopulations for individual treatment. In each cluster, we compare the global rotation signal with that of each subpopulation, as well as the spatial distributions of the subpopulations. We compare these results to expectations from models for the formation of multiple populations in globular clusters.

152.07 – **Chemical Compositions of Stars in the Globular Cluster NGC 3201: Tracers of Multi-Epoch Star Formation**

Jennifer A. Simmerer[1], I. I. Ivans[1], D. Filler[1]

[1]*University of Utah.*
9:00 AM - 6:30 PM

The retrograde halo globular cluster NGC 3201 contains stars of substantially different iron abundance ([Fe/H]), a property that puts it at odds with the vast majority of the Galactic cluster system. Though its unusual orbit prompted speculation that NGC 3201 was the remnant of a captured object, much like the multi-metallicity globular cluster Omega Centauri, NGC 3201 is much less massive than Omega Centauri and all of the other halo globular clusters that have internal metallicity variations. We present the abundances of 21 elements in 24 red giant branch stars in NGC 3201 based on high-resolution (R~40,000), high signal-to-noise (S/N~70) spectra. We find that the detailed abundance pattern of NGC 3201 is unique amongst multi-metallicity halo clusters. Unlike M22, Omega Centauri, and NGC 1851, neither metal-poor nor metal-rich stars show any evidence of s-process enrichment (a product of the advanced evolution of low- and intermediate-mass stars). We find that while Na, O, and Al vary from star to star as is typical in globular clusters, there is no systematic difference between the abundance pattern in the metal-poor cluster stars and that of the metal-rich cluster stars. Furthermore, we find that the metallicity variations in NGC 3201 are independent of the well-known Na-O anticorrelation, which separates it from every other multi-metallicity cluster. In the context of a multi-episode star formation model, this implies that NGC 3201 began life with the [Fe/H] variations we measure now.

152.08 – **Comparisons Of Lighter Neutron-capture Elements In Galactic Halo Stars**

Jacob Teffs[1], T. Odekirk[1], D. L. Burris[1]

[1]*University of Central Arkansas.*
9:00 AM - 6:30 PM

There are two main processes involved in the creation of elements with a Z > 30; the "rapid" r-process, and the "slow" s-process. The r-process and s-process are neutron-capture processes, meaning that starting with a base nuclei, they capture neutrons which then beta decay into a proton and an electron.

The r-process requires extreme conditions: high neutron fluxes and high temperatures thus limiting the environments where it can occur. Current understanding of these processes alone does not appear to account for all n-capture isotopic abundances observed.

We are able to reproduce an earlier result shown by Burris et al (2000) that showed that Ba had a bimodal trend when compared to Eu. This indicates that Ba is created by the r-process early in the Galaxy's history. We propose to look for such trends in the lighter n-capture elements such as Yttrium, Zirconium and Strontium. These elements are of interest since they do not appear to have a single r-process component responsible for their production. Using survey stars from Simmerer et al (2004) new abundance values for these elements have been determined. Element to element comparisons have been conducted to search for trends similar to those known for main r-process elements as well as similarities between the lighter n-capture elements.

152.09 – **Open Cluster Neutron Capture Element Abundances and Milky Way Disk Evolution**

Heather R. Jacobson[1], E. D. Friel[2]

[1]*Michigan State Univ.,* [2]*Indiana Univ..*
9:00 AM - 6:30 PM

Open clusters, whose ages and distances can be precisely determined, are useful probes of the chemical evolution of the Milky Way disk. The sample sizes of clusters subject to homogeneous analysis of high resolution spectra have grown in recent years, and increased attention has turned to measuring the abundances of neutron capture elements. The relative abundances of r-process elements (e.g., europium) to s-process elements (e.g., barium, lanthanum and zirconium) in cluster stars reveal the relative contributions of Type II supernovae and low-mass AGB stars to the chemical evolution of the galactic disk. A recent study of cluster s-process element abundances has revealed a surprising trend of increasing s-process element abundance ([s/Fe]) with decreasing cluster age, at odds with current s-process yield predictions (D'Orazi et al. 2009, Maiorca et al. 2011). We have undertaken an analysis of Zr, Ba, La, and Eu abundances in 17 open clusters based on high resolution optical spectra. The sample spans ~700 Myr to 10 Gyr in age and R_{gc} ~7-22 kpc in galactocentric distance, allowing for the exploration of neutron capture [x/Fe] ratios as a function of age and location in the disk. Preliminary results confirm the trend of enhanced [s/Fe] with decreasing cluster age found by other studies, though with a weaker correlation. Here we present the latest results of this analysis, including newly-determined abundances for the

r-process element Eu for an expanded cluster sample that includes outer disk objects. This research is supported by a National Science Foundation Astronomy and Astrophysics Postdoctoral Fellowship to HRJ under award AST-0901919.

152.10 – **Solving the Ca II Triplet Puzzle for Elliptical Galaxies**

Christopher J. Miller[1], K. S. Krughoff[2], J. W. Richards[3], M. Bergmann[4]

[1]University of Michigan, [2]University of Washington, [3]University of California, Berkeley, [4]Gentleman Astronomer.

9:00 AM - 6:30 PM

The Ca II triplet is a prominent absorption-line feature in the near-infrared spectrum of cool stars. In elliptical galaxies, it has been shown to be nearly age independent for stellar populations older than a few gigayears. Along with the strong dependence of the Ca II Triplet on metallicity and when combined with new infrared spectrometers, the Ca II Triplet could provide a means to measure metallicities in high redshift galaxies. However, recent observations of the index in nearby galaxies has shown that it is lower than expected from simple stellar population modeling. We show that after accounting for composite stellar populations and local galaxy environments, the Ca II Triplet is entirely in-line with synthesis models.

152.11 – **The Chemical Composition of RGB Stars in Off-Axis Bulge Fields**

Christian I. Johnson[1], R. Rich[1], A. Kunder[2], R. de Propris[2], C. Kobayashi[3], A. Koch[4]

[1]University of California, Los Angeles, [2]Cerro-Tololo Inter-American Observatory, Chile, [3]The Australian National University, Australia, [4]University of Heidelberg, Germany.

9:00 AM - 6:30 PM

We present chemical abundances of several light, alpha, Fe-peak, and neutron-capture elements in >100 red giant branch (RGB) stars for three separate off-axis bulge fields. The abundances were determined from equivalent width and spectrum synthesis analyses using high resolution (R=18,000), high S/N (70-100) spectra obtained with the Hydra multi-fiber spectrograph on the Blanco 4m telescope at CTIO. We compare our results in these off-axis fields with those along the bulge minor axis. Additionally, the off-axis abundance trends are compared with other Galactic stellar populations and a bulge chemical enrichment model. This material is based upon work supported by the National Science Foundation under award No. AST-1003201 to C.I.J. and award No. AST-0709479 to R.M.R.

152.12 – **Age, Period, And Inclination Determination For Stars In The Debris Survey**

Laura Vican[1], B. Zuckerman[1]

[1]UCLA.

9:00 AM - 6:30 PM

The age of a star is one of its most fundamental properties, but one of hardest to calculate directly. One way to do this is to take advantage of the relationship between a star's chromospheric activity level (a function of the activity parameter R'(HK)) and its age. We applied this method to stars in the DEBRIS (Disk Emission via a Bias-free Reconnaissance in the Infrared/Submillimeter) survey. So far, we have used chromospheric activity to determine the ages of more than 200 of our F, G, and K-type stars (with an average error of about 15%). These ages range from 1 Myr to almost 10 Gyr. 45 of these have no known published ages. Besides the age of our sample, we would also like to know something about the rotational properties of these stars. Using the known activity-rotation relation, we can calculate the rotation period of our stars. Since rotation affects the calculation of many stellar parameters (age, surface gravity, temperature, etc), it would be useful to know the actual rotation period, rather than just the line-of-sight rotational velocity, vsin*i*. We have calculated rotation periods for more than 200 of our F, G, and K-type stars (with an average error of about 10%). Some of these stars have photometrically determined rotation periods in the literature, which are (in general) in good agreement with our calculated periods. As a continuation of this project, we plan to use published vsin*i* and radius data along with our calculations for Prot to calculate an inclination for the system. This will be useful in determining the morphology of the magnetic fields, debris disks, and planetary orbits around these stars.

152.13 – **Rotation Periods of the Hyades Open Cluster using ASAS Light Curves: Measuring the Hyades Gyro-Age and Benchmarking Tools for Gyrochronology Studies with LSST**

Alisha Kundert[1], P. A. Cargile[1], S. Dhital[1], L. Hebb[1], J. Rostron[2], K. G. Stassun[1]

[1]Vanderbilt University, [2]Warwick University, United Kingdom.

9:00 AM - 6:30 PM

Rotation period distributions for older open clusters are difficult to obtain because of the general scarcity of clusters with ages greater than 200 Myr and the challenge in measuring rotation periods for less active older stars. This has clouded our knowledge of how stars spin down as they evolve from the zero-age main sequence. A key piece of our understanding of how stellar rotation rates change over time relies on the study of the nearby (~45 pc) and old (~650 Myr) Hyades open cluster. We present the results from a detailed analysis of the rotation period distribution of the Hyades in an effort to estimate the gyro-age of this benchmark open cluster. Analyzing All Sky Automated Survey (ASAS) light curves with 10+ year baselines, we measure rotation periods for Hyads by applying a period-finding technique that combines the Lomb-Scargle periodogram with Monte Carlo simulations to optimize period detection in long-baseline, low-cadence data which might suffer from time-dependent changes in the light curve, e.g. star spot evolution. We derive rotation periods for known Hyades members, of which a significant number are newly determined periods not currently found in the literature. These rotation periods measured from ASAS light curves allow us to characterize the rotation period distribution of the Hyades, enabling the application of current gyrochronology models to calculate a precise rotation-age for the cluster. Additionally, using ASAS data provides a valuable test of determining rotation periods in future low-cadence, extended duration surveys, such as the Large Synoptic Survey Telescope (LSST), and assesses our ability to estimate stellar ages via gyrochronology from sparsely sampled, long-baseline light curve data.

152.14 – **A Bayesian Approach to Parameters of Galactic Globular Clusters**

Roger Cohen[1], T. von Hippel[2], A. Dotter[3], A. Sarajedini[1], N. Stein[4], E. Jeffery[5], M. Montgomery[6], D. A. van Dyk[7]

[1]Univ. Of Florida, [2]Embry-Riddle Aeronautical University, [3]Space Telescope Science Institute, [4]Harvard University, [5]James Madison University, [6]Univ. Of Texas Austin, [7]Imperial College, United Kingdom.

9:00 AM - 6:30 PM

We describe the use of a Bayesian approach to determine several parameters for Galactic globular clusters (GGCs). These parameters include age, metallicity, distance modulus, reddening, binarity and cluster membership. By sampling the posterior distributions of these parameters using a Markov Chain Monte Carlo (MCMC) technique, we can produce parameter estimates with well quantified uncertainties. We use a grid of synthetic clusters with a range of parameters to assess any systematic effects of our approach on the resultant cluster properties. We then apply the code to a set of homogenous GGC photometric catalogs which we have generated. These catalogs consist of HST and 2MASS photometry ranging from near-UV to infrared bandpasses, allowing us to explore the influence of different filter combinations on recovered cluster parameters. Not only can these results be used to inform future large-scale investigations from an observational standpoint, but we also suggest several key areas of stellar astrophysics which may benefit from detailed studies incorporating our technique.

152.15 – **Rotation Period of Blanco 1 Members from KELT Light Curves: Comparing Rotation-Ages to Various Stellar Chronometers at 100 Myr**

Phillip Cargile[1], D. J. James[2], J. Pepper[1], R. Kuhn[3], R. J. Siverd[1], K. G. Stassun[1]

[1]Vanderbilt Univ., [2]Cerro Tololo Inter-American Observatory, Chile, [3]University of Cape Town, South Africa.

9:00 AM - 6:30 PM

The age of a star is one of its most fundamental properties, and yet tragically it is also the one property that is not directly measurable in observations. We must therefore rely on age estimates based on mostly model-dependent or empirical methods. Moreover, there remains a critical need for direct comparison of different age-dating techniques using the same stars analyzed in a consistent fashion. One chronometer commonly being employed is using stellar rotation rates to measure stellar ages, i.e., gyrochronology. Although this technique is one of the better-understood chronometers, its calibration relies heavily on the solar datum, as well as benchmark open clusters with reliable ages, and also lacks a comprehensive comparative analysis to other stellar chronometers. The age of the nearby (~250 pc) open cluster Blanco 1 has been estimated using various techniques, including being one of only 7 clusters with an LDB age measurement, making it a unique and powerful comparative laboratory for stellar chronometry, including gyrochronology. Here, we present preliminary results from our light-curve analysis of solar-type stars in Blanco 1 in order to identify and measure rotation periods of cluster members. The light-curve data were obtained during the engineering and calibration phase of the KELT-South survey. The large area on the sky and low number of contaminating field stars makes Blanco 1 an ideal target for the extremely wide field and large pixel scale of the KELT telescope. We apply a period-finding technique using the Lomb-Scargle periodogram and FAP statistics to measure significant rotation periods in the KELT-South light curves for confirmed Blanco 1 members. These new rotation periods allow us to test and inform rotation evolution models for stellar ages at ~100 Myr, determining a rotation-age for Blanco 1 using gyrochronology, and compare this rotation-age to other age measurements for this cluster.

152.16 – **Color Distributions of Stars in the WISE Preliminary Data Release**

Nicholas Hunt-Walker[1], J. R. A. Davenport[1], A. R. Lewis[1], J. Ruan[1], L. Anderson[1], Y. AlSayyad[1], A. Becker[1], Z. Ivezic[1]

[1]University of Washington - Seattle.

9:00 AM - 6:30 PM

We present a preliminary characterization of the Galactic stellar populations from the Wide-field Infrared Space Explorer (WISE) Preliminary Data Release. We trace the main sequence color locus in 16 dimensions using a matched sample between IRAS, SDSS and 2MASS for several million stars. This exquisite characterization of "normal" stars enables efficient and robust searches for non-main-sequence stars. For example, the excellent faint limit of WISE yields a sample of AGB candidates using the 4.6, 12, and 22 micron bandpasses that exceeds the IRAS AGB catalog by up to an order of magnitude. Our preliminary analysis suggests that the WISE database will be a goldmine for studies of Galactic stellar populations.

152.17 – **Spectral Classification of Massive Stars in M31 and M33**

Brianna Smart[1], P. Massey[2], D. R. Silva[3]

[1]*University of Arizona,* [2]*Lowell Observatory,* [3]*NOAO.*

9:00 AM - 6:30 PM

M31 and M33 are important galaxies to study when trying to understand stellar evolution. We observed 1,717 objects at the 6.5-m MMT using the 300-fiber fed spectrometer, Hectospec, in order to find massive stars in M31 and M33, of which 904 were from sources in M31 and M33. Of these sources, 129 O-type, 601 B-type supergiant, 81 A-type supergiant, 26 G-type supergiant, 20 F-type supergiant, 22 LBV candidates, and 25 Wolf-Rayet stars were classified. By finding the relative number of different massive stars in M31 and M33, the data can help refine stellar evolution models of massive stars by putting constraints on such models. In addition, these classifications were added to the photometry taken in the Local Group Galaxy Survey (Massy 2006) to make a more thorough catalog of sources in the direction of M31 and M33. This project was made possible by support from the National Science Foundation, through grants AST-1004107 and AST-1005313.

152.18 – **Is the Sun a Good Solar Twin?**

Laurence E. DeWarf[1], E. F. Guinan[1], S. G. Engle[1], J. A. Robertson[1], J. M. DePasquale[2]

[1]*Villanova Univ.,* [2]*Harvard/Smithsonian CfA.*

9:00 AM - 6:30 PM

We have been involved in a comprehensive study of the evolution of coronal (X-ray; Einstein/ROSAT/ASCA/XMM/Chandra), transition-region (FUV;

IUE/FUSE/HST), and chromospheric (FUV-UV; IUE/HST) emissions of solar-type stars with a wide range of ages. This project uses a sample of solar analogs, narrowly confined between spectral types G0-5 V that vary only by their (reasonably) well determined ages and rotation periods, and hence magnetic activity. An important component of this "Sun in Time" project focuses on the identification of stars whose properties are most like the Sun (solar twins). Additionally, this study provides an important check on the magnetic behavior of our present Sun and solar-like stars. For example, is our Sun "normal" for its age and mass?

Studies of cosmogenic isotopes have been employed to trace the Sun's activity back over the last ~12,000 years. Curiously, this study reveals that the solar magnetic activity (defined by solar winds and sunspots) appears to have been exceptionally high over the last ~70 years, but is perhaps declining now. This may help to explain the apparently low (relative to the present Sun) coronal soft X-ray luminosities observed for the solar analog alpha Cen A. Three other well-studied solar-type stars (18 Sco, 16 Cyg A and B) also appear to have X-ray emissions considerably lower than current solar values. 18 Sco is the best known match to the Sun with regard to age, rotation, and physical properties, and has an observed X-ray luminosity (logL=26.9 cgs at the maximum of its 7-11 year activity cycle) that is comparable to the maximum value for the older alpha Cen A (logL=27), but less than one half of the present solar max values (logL=27.9).

This research is supported by grants from NASA/Chandra (GO101Q035X), NASA/HST (GO-12303), and NSF/RUI (1009903).

153 – Binary Stellar Systems: X-ray Binaries

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

153.01 – **Recent Integral Observations Of The Galactic Center Region: The Black Hole X-ray Binary Grs 1758-258 And The Enigmatic X-ray Binary 4u 1700-377**

Aisha Mahmoud[1], K. Pottschmidt[2], V. Grinberg[3], D. Marcu[2], A. M. Lohfink[4], M. Obst[3], M. Cadolle[5], I. Kreykenbohm[3], J. Wilms[3]

[1]*University of Arkansas-Fayetteville,* [2]*University of Maryland, Baltimore/CRESST & NASA Goddard Space Flight Center,* [3]*Dr. Remeis Observatory, Germany,* [4]*U. of Maryland, College Park,* [5]*ESAC, Spain.*

9:00 AM - 6:30 PM

We present preliminary results of X-ray monitoring observations of the Galactic Center region measured between 2009 and 2011 with the INTEGRAL satellite. Our first goal was to search for new transient sources in the field. A sensitive search, averaging over three-day datasets, yielded no new source detections in the 20-40 keV range. Also, we present results from the Swift-BAT and INTEGRAL-ISGRI instruments of two X-ray binary systems that fall among the least understood: the persistent black hole candidate GRS1758-258 and the pulsar candidate 4U1700-377. GRS1758-258 shows large long-term flux variations with very rare soft-state events. We find that the INTEGRAL-ISGRI spectra of this source do not allow to detect significant variation on a timescale of days. We confirmed that the spectral shape is generally well recovered even at extremely large offset angles, but that these spectra show strong systematic noise. 4U1700-377 shows frequent, strong, but short flux variations. Accordingly, the INTEGRAL-ISGRI spectra show significant fluctuations in flux on short timescales.

153.02 – **X-ray Binaries in the Ultrahigh Collision Rate Globular Cluster NGC 6388**

James Edward Maxwell[1], H. N. Cohn[1], P. M. Lugger[1], C. O. Heinke[2], S. A. Budac[2]

[1]*Indiana University,* [2]*University of Alberta, Canada.*

9:00 AM - 6:30 PM

We report on the final results of a joint *Chandra/HST* study of the X-ray binary population in the massive, high-density globular cluster NGC 6388. NGC 6388 has the highest predicted X-ray binary production rate of any Galactic cluster and, indeed, we detected a large population of 61 *Chandra* sources within the half-mass radius with $L_X > 4 \times 10^{30}$ ergs s^{-1}. Based on the X-ray colors of these sources, four are suggestive of quiescent low-mass X-ray binaries and five are suggestive of cataclysmic variables. We have identified four blue, optically variable counterparts to X-ray sources, evidence that these are bright CVs. One showed variability of 2 magnitudes in V, indicative of a dwarf nova eruption. The optical magnitudes of these sources put them in the same class as CV1 in M15 and the brightest CVs in 47 Tuc.

153.03 – **New Interacting Binaries Identified by the Chandra Galactic Bulge Survey**

Christopher Britt[1], R. I. Hynes[1], P. G. Jonker[2], C. G. Bassa[3], G. Nelemans[4], D. Steeghs[5], M. A. P. Torres[2], T. J. Maccarone[6], S. Greiss[5], V. J. Mikles[1], L. Gossen[1], A. C. Collazzi[1], Galactic Bulge Survey Collaboration

[1]*Louisiana State University,* [2]*SRON, Netherlands Institute for Space Research, Netherlands,* [3]*University of Manchester, United Kingdom,* [4]*Radboud University, Netherlands,* [5]*University of Warwick, United Kingdom,* [6]*University of Southampton, United Kingdom.*

9:00 AM - 6:30 PM

The Chandra Galactic Bulge Survey (CGBS) is a shallow X-ray survey of 2 6x1 degree strips above and below the Galactic Plane, where extinction and crowding are substantially lower than in the plane itself. The strategy for the CGBS is to go deep enough in the X-ray to see quiescent Low Mass X-ray Binaries (qLMXB), but to remain shallow enough to avoid an overabundance of Cataclysmic Variables (CVs), with the goal of testing binary evolution models and greatly expanding the sample of LMXBs for optical follow up including mass determination. We present classification of selected X-ray emitting interacting binaries out of 1234 X-ray sources identified in the CGBS. Each source exhibits emission lines in its optical/IR spectrum. The optical variability of each source was also examined to determine lightcurve morphology and periodicity. Combining spectral information, lightcurve morphology, and X-ray to optical flux ratios enables classification of each of these sources.

This work is supported by the National Science Foundation under Grant No.AST-0908789.

153.04 – **An Emission Line Survey for Fields Around High Mass X-Ray Binaries**

Michael D. Joner[1], E. G. Hintz[1]

[1]*Brigham Young Univ..*

9:00 AM - 6:30 PM

To support our current observing program monitoring High Mass X-ray Binary (HMXB) systems for optical variability, we have observed a sample of comparison stars in the fields of several known HMXB systems using calibrated H-alpha and H-beta photometric systems. The observations were secured using the West Mountain 0.9-m telescope. The calibrations were established using multiple spectroscopic observations of H-Beta standards along with cluster stars from the Hyades and Coma clusters obtained with the 1.2-m telescope at the Dominion Astrophysical Observatory. We report the first results for our program to identify and characterize the variable emission observed in the optical counterpart for each HMXB system.

We would like to thank the Brigham Young University College of Physical and Mathematical Sciences for continued support of research work at the West Mountain Observatory. Partial support for this project was derived from NSF grant AST #0618209.

153.05 – **Optical Observations of the Black Hole LMXB J1118+480**

Lorena Monroy[1], P. A. Mason[1], E. L. Robinson[2], A. J. Bayless[3]

[1]University of Texas at El Paso, [2]University of Texas at Austin, [3]Southwest Research Institute (SwRI).

9:00 AM - 6:30 PM

We present optical observations of the black hole X-ray binary J1118+480 obtained, on 12 nights during 2010 and a single night in June 2011, using the McDonald Observatory 2.1-m Otto Struve Telescope and Argos photometer using a BVR filter. J1118+480 is an X-ray transient currently in quiescence. A period study yields a period of P = 0.08496672 +/- 0.00000024 days. We derive a zero point crossing (negative to positive) of T(zero) = 2455324.60280 +/- 0.00025 HJD The light curves clearly show large amplitude sinsoidal variation at 1/2 of the orbital period. There is a hint that one of the ellipsoidal variation minima may be deeper, at times, than the other. Additional, planned, observations are expected to yield a precise long-term ephemeris and more fully characterize the ellipsoidal variations. This work is part of the NSF/PAARE program for Education and Research.

153.06 – **The LMXB Population of the Nearest Large Elliptical Galaxy: Implications on the Distance to Maffei 1**

Ann Kathryn Rockwell[1], J. A. Irwin[1]

[1]University of Alabama.

9:00 AM - 6:30 PM

As a member of the Maffei 1 group of galaxies that also includes Maffei 2 and IC342, Maffei 1 is the nearest normal large elliptical galaxy. Its distance, however, is the subject of debate with estimates ranging from 2.9-4.1 Mpc, with much of the confusion stemming from the large absorbing column density toward this low Galactic latitude galaxy. We have used Chandra to study the low-mass X-ray binary (LMXB) population of Maffei 1, which is only minimally affected by the large absorption as compared to optical and near-infrared wavelengths. Assuming a smaller distance for Maffei I leads to a dearth of LMXBs with luminosities in the 2-5 x 10^{38} ergs/s range as would be expected from a large elliptical galaxy. We discuss how the luminosity function of the LMXBs can lead to constraints on the distance to Maffei I. The nearness of Maffei 1 also allows us to probe the faint end of the LMXB luminosity function to depths comparable to other much longer observed elliptical galaxies with only a modest 55 ksec observation.

153.07 – **Optical Photometry of the Black Hole Candidate SWIFT J1753.4-0126**

Aurelio Paez[1], P. A. Mason[1], E. L. Robinson[2], A. J. Bayless[3]

[1]University of Texas at El Paso, [2]University of Texas at Austin, [3]Southwest Research Institute (SwRI).

9:00 AM - 6:30 PM

We present optical observations of the black hole candidate LMXB SWIFT J1753.4-0126 with the 2.1m Otto Struve Telescope of McDonald Observatory. The Argos CCD photometer was used and 10s integrations were obtained on 19 nights in 2010 and 2011. We performed a period search using a Phase Dispersion Minimization (PDM) code and we obtain a period of 3.2448 +/- 0.0002hr. This new period is fully consistent with, and a factor of 5 improvement over, the PDM period of (Zurita et al. 2008). The individual light curves are complex and variable.

This work is part of the NSF/PAARE program for Education and Research.

153.08 – **Observations of Ellipsoidal Variations in the LMXB V1727 Cygni**

Alex Price[1], P. A. Mason[1], E. L. Robinson[2]

[1]University of Texas at El Paso, [2]University of Texas at Austin.

9:00 AM - 6:30 PM

We report the first detection of ellipsoidal variations in the quiescent low mass X-ray binary, V1727 Cygni. We obtained 10s integrations over 19 nights during 2010-2011, with ~1 orbital period observed each night using the 82in,

Otto Struve Telescope, of McDonald Observatory. A power spectrum analysis detected a signal at 1/2 of the orbital period. The detected period is at 0.10913 +/- 0.00001 days, giving an orbital period of 0.21826 +/- 0.00002 days. The amplitude of the variations is small due to the strong dilution of optical light from an F-type star, apparently in a hierarchal triple with the LMXB. Thorstensen (1979) observed the system in outburst with an amplitude of ~1 mag at the orbital period, and nothing at half the orbital period. We see no power at the orbital period, because the ellipsoidal variations display nearly identical minima. Comparison with light curve model calculations suggest that a small amount of X-ray heating is taking place, consistent with the compact object being a neutron star. This work is part of the NSF/PAARE program for Education and Research.

153.10 – **Radial Velocity Variations In The Gamma-ray Binary HESS J0632+057**

M. Virginia McSwain[1], C. Aragona[1], A. N. Marsh Boyer[1], S. D. Bongiorno[2], R. L. Bowers[1], N. L. Hernandez[1]

[1]Lehigh Univ., [2]Penn State.

9:00 AM - 6:30 PM

The TeV source HESS J0632+057 was recently found to exhibit X-ray flux variability with a period of 320 +/- 5 days. The time of X-ray maximum may correspond to periastron in this interacting binary, and it may be possible to detect radial velocity variations at this orbital phase. Here we present KPNO Coude Feed spectra of the proposed optical counterpart, HD 259440, during the Dec. 2011 X-ray maximum. We use the observed radial velocities to constrain the orbital geometry of the system and discuss the implications for the very high energy production.

We are grateful for support from NSF grant AST-1109247, the Sigma Xi Grant-in-Aid of Research program, and Lehigh University.

153.11 – **The Distance of the Gamma-ray Binary 1FGL J1018.6-5856**

Vanessa Napoli[1], M. V. McSwain[2], A. N. Marsh Boyer[2], R. M. Roettenbacher[3]

[1]The Catholic University of America, [2]Lehigh Univ., [3]Univ. Michigan.

9:00 AM - 6:30 PM

The recently discovered gamma-ray binary 1FGL J1018.6-5856 has a proposed optical/near-infrared (OIR) counterpart 2MASS 10185560-5856459. We present Stromgren photometry of this star to investigate its photometric variability and measure the reddening and distance to the system. We find that the gamma-ray binary has E(B-V) = 1.34 +/- 0.04 and d = $5.4^{+4.6}_{-2.1}$ kpc. While E(B-V) is consistent with X-ray observations of the neutral hydrogen column density, the distance is somewhat closer than some previous authors have suggested.

We are grateful for support from NSF grants PHY-0849416 and AST-1109247, the NASA Harriett G. Jenkins Pre-doctoral Fellowship program, the Sigma Xi Grant-in-Aid of Research program, and Lehigh University.

153.12 – **HST/COS Observations of X-ray Binaries**

Cynthia S. Froning[1], E. Robinson[2], R. Hynes[3], T. Maccarone[4], K. France[1]

[1]Univ. of Colorado, [2]University of Texas at Austin, [3]Louisiana State University, [4]University of Southampton, United Kingdom.

9:00 AM - 6:30 PM

We have obtained FUV spectroscopy of the X-ray binaries A0620-00, 4U0614+091, and MS1603.6+2600 using the Cosmic Origins Spectrograph on HST. The UV observations have been accompanied by contemporaneous multiwavelength X-ray, optical/NIR, and (for A0620-00) radio observations. The data provide constraints on the structure of the accretion disk and disk outflows, the evolutionary histories of the systems, and the physical properties of the accreting material. We will present the observations and analysis of the multiwavelength data.

153.13 – **The Optical Orbital Light Curve of V1408 Aquilae (= 4U 1957+115): A Black Hole Candidate That Is Really a Neutron Star?**

Edward L. Robinson[1], A. J. Bayless[2], P. A. Mason[3], P. Robertson[1]

[1]Univ. of Texas, [2]Southwest Research Institute, [3]Univ. of Texas at El Paso.

9:00 AM - 6:30 PM

V1408 Aql is a low-mass X-ray binary with an orbital period of 9.329 hrs. Its optical orbital light curve has previously been measured by Thorstensen (1987), who found a sinusoidal modulation that he attributed to the irradiated face of the secondary star; and it has been measured by Hakala et al. (1999), who, based on their much smaller but multicolor data set, attributed the modulation to partial eclipses of a thick accretion disk around the compact star. Their model implies an orbital inclination near 75^{o}. Using this inclination, Nowak et al. (2008) modeled the X-ray spectrum of V1408 Aql and concluded that its compact star is a rapidly rotating black hole.

We have obtained extensive optical photometry of V1408 Aql. The average orbital light curve is nearly sinusoidal with a peak-to-peak amplitude of 23%. The RXTE/ASM X-ray light curve shows no periodicities at or near the orbital period. We show that a model in which the orbital modulation is caused by the varying aspect of the heated face of the secondary star yields excellent fits to the mean light curve. There is no eclipse, limiting the orbital inclination to less than 70^{o}. The mass ratio M_2/M_X is unlikely to be small because: (1) the large amplitude of the sinusoidal variation favors a large secondary, which in turn favors a larger mass ratio, and (2) there is no evidence for superhumps, which are often present in light curves when the mass ratio is less than ~0.25. The larger mass ratio means the compact star is more likely to be a neutron star than a black hole.

153.14 – **A Numerical Model for Absorption Dips and Comparison with Observations of Hercules X-1**

Denis A. Leahy[1], C. D. Igna[1]

[1]Univ. of Calgary, Canada.

9:00 AM - 6:30 PM

We calculate light curve absorption dips produced by accretion stream impact on the

disc in an X-ray binary. The dips are produced whenever the impact region on the disc blocks the observers line-of-sight (LOS) to the neutron star. The particular X-ray binary we consider is Her X-1, which has a large inclination so that the observers LOS passes near the disk surface and can readily be blocked by a small impact region. We compare calculated dip times to observed dip timings (Leahy and Igna 2011, ApJ,736, 73 and Igna and Leahy, 2011, MNRAS in press) and find that in order to produce a wide enough range of orbital phase and 35-day occurence of dips, we need to allow disc penetration by the stream, so that the stream can proceed to a second impact with the disc. With this extra feature we can reproduce the observed dips timings.

153.15 – **X-rays from Blue Compact Dwarf Galaxies**

Joseph Schmitt[1], P. Kaaret[1], M. Gorski[2]

[1]*University of Iowa,* [2]*University of New Mexico.*
9:00 AM - 6:30 PM

The origin of ionizing photons in the reionization epoch is an important and open question. It has been proposed that X-ray binaries had a significant impact on the intergalactic medium in this epoch. We studied X-ray binaries in all blue compact dwarf galaxies (BCD's), often considered to be local analogs to early galaxies, within 15Mpc with metallicities <0.07Z solar. We found that the total X-ray luminosity of the sample is ten times greater than one would expect scaling from the relation with star formation rate for normal metallicity galaxies. However, due to the low number of detected sources, one can only exclude the hypothesis that the relation for BCD's is the same at the 96.6% confidence interval. This suggests that X-ray binary production may have had an enhanced impact in the early thermal history of the universe.

153.16 – **The Relation Between Disk Scale-Height and Jet Power in GRMHD Simulations**

Julia Wilson[1], P. Fragile[1], M. Rodriguez[1]

[1]*College of Charleston.*
9:00 AM - 6:30 PM

It is now well established that changes in the X-ray spectral state of black hole X-ray binaries are correlated with changes in the radio properties of those systems. Assuming radio power is a proxy for jet power, we can say that the jet is steady in the hard state and undetectable (and therefore weaker) in the soft state. Since the different accretion states are also generally assumed to be associated with different disk geometries -- the hard state associated with a hot, thick flow, and the soft state with a cold, thin disk -- we investigate the possibility that these two phenomena are linked; i.e., that the difference in disk geometry is the cause for the difference in observed jet power between spectral states. We do this by comparing various measures of jet power in numerical simulations of accretion disks of differing temperatures and thicknesses. We perform these simulations using the general relativistic magnetohydrodynamic code Cosmos++ and a newly added cooling function, which allows us to regulate the disk scale height h/r at different radii.

153.17 – **Modelling The Coupling Of Variability And Spectral Emission In Black Hole X-ray Binaries**

Pablo Cassatella[1], P. Uttley[2], J. Houck[3], J. E. Davis[3]

[1]*University of Southampton, United Kingdom,* [2]*University of Amsterdam, Netherlands,* [3]*MIT.*
9:00 AM - 6:30 PM

The emission properties of Black Hole X-ray Binaries (BHXRBs) are commonly studied either in terms of their energy spectrum (counts per energy channel) or in terms of their variability properties by means of power spectral density. Each of these can be modelled separately using X-ray analysis packages, however energy spectra and frequency power spectra have not been modelled simultaneously so far to produce a self-consistent picture of the origin and transfer of variability in these systems. We discuss new techniques that use frequency and energy-dependent cross-spectra in different energy channels to model variability and spectral information simultaneously. The powerful combination of spectral and timing information will allow us to 'reverberation map' the emitting regions close to the black hole and measure the propagation of signals through the accretion flow.

153.18 – **Ultraviolet Spectra of ULX Systems**

Julie Felberg[1], J. Bregman[1], P. J. Seitzer[1], J. Liu[2], M. Kuemmel[3]

[1]*University of Michigan,* [2]*Harvard,* [3]*SpaceTelescope Science Institute.*
9:00 AM - 6:30 PM

To further understand the nature of the optical counterparts associated with Ultraluminous X-Ray sources (ULXs), we obtained far ultraviolet spectra of the reported counterparts to the ULXs in NGC 1313, Holmberg II, NGC 5204, and M81. The spectral resolution of the ACS prism spectra degrades from 300 at 1300 A to 40 at 1850 A, so longer wavelength features have lower S/N. The spectra of the ULXs in NGC 1313, Ho II, and NGC 5204 are quite similar, showing the N V 1240 line at about the same equivalent width strength. The presence of this and other emission lines confirms the presence of an accretion disk, probably diluted by the light of an early B star companion. The spectra differ strongly from high mass X-ray binaries dominated by O star winds (e.g., Cyg X-1) and most similar to intermediate mass black hole systems in the Milky Way and LMC. The weak spectrum of the ULX in M81 is suggestive of a late-type Wolf-Rayet star. We gratefully acknowledge support from NASA grant NNX10AH83G.

153.19 – **Modeling The Evolution Of Low Mass X-Ray Binaries In Globular Clusters**

Sanghamitra Goswami[1]

[1]*Northwestern University.*
9:00 AM - 6:30 PM

X-ray surveys have discovered 150 low-mass X-ray binaries (LMXBs) in our Galaxy and, with Chandra and XMM, many more were found in other galaxies. Globular clusters, with their high stellar densities and high rates of dynamical encounters, provide a natural place to manufacture these LMXBs. We present a detailed study of LMXB formation and evolution in globular clusters using a dynamical Monte Carlo code coupled to a Binary Stellar Evolution code (BSE). Our Monte Carlo code allows us to perform realistic globular cluster simulations with up to ~10^6 stars and significant binary fractions. Moreover, in BSE we have now included a detailed prescription for electron capture supernovae, accretion induced collapse, and tidal interactions during a binary encounter. We have also implemented a detailed treatment of pulsar physics, including magnetic field decay during mass accretion. Using this numerical set up we can compare our models of globular clusters directly to observations of LMXBs and pulsars. We can also test the possibility that LMXBs formed in clusters may get ejected, thereby populating the field. Furthermore, we can use data on radio pulsar systems in clusters to test the basic paradigm that binary encounters and interactions play a dominant role in the formation of both millisecond pulsars and LMXBs.

153.20 – **Searching for Optical Variability from X-ray Sources in the Galactic Bulge Survey**

Victoria Villar[1], R. I. Hynes[2], C. T. Britt[2], P. G. Jonker[3], C. G. Bassa[4], G. Nelemans[5], S. Danny[6], M. A. Torres[3], T. J. Maccarone[7], S. Greiss[6], E. M. Ratti[3], V. J. Mikles[2], L. Gossen[2], A. C. Collazzi[2]

[1]*Massachusetts Institute of Technology,* [2]*Louisiana State University,* [3]*SRON, Netherlands Institute for Space Research, Netherlands,* [4]*University of Manchester, United Kingdom,* [5]*Radboud University, Netherlands,* [6]*University of Warwick, United Kingdom,* [7]*University of Southampton, United Kingdom.*
9:00 AM - 6:30 PM

The Chandra Galactic Bulge Survey (CGBS) is a 6-degree wide, X-ray survey a degree above and below the galactic plane. This survey searches for X-ray binary systems in a region of manageable optical extinction and crowding, allowing for analysis of optical counterparts. A primary goal of the CGBS is to increase the catalog of known low mass X-ray binary systems and to analyze the distribution of periodicities and varieties of x-ray sources. My research focuses on the variety of fluctuations found in 50 optical candidate counterparts to CGBS sources. Over half of these sources show variability in optical flux, with a majority of this showing strong evidence of periodic trends or outburst characteristics. I focus, also, on a particularly intriguing interacting binary for which we are obtaining full dynamical information. Additional, multiwavelength follow-up is expected for notable objects, such as this interacting system, in the future. This work is supported by the National Science Foundation under Grant No. AST-0908789. Victoria Villar also acknowledges support from the REU Site in Physics and Astronomy (NSF Grant No. 1004822) at Louisiana State University.

153.21 – **Rapid Response Galactic X-ray Transient Follow-up with Swift**

Jamie A. Kennea[1]

[1]*Penn State Univ..*
9:00 AM - 6:30 PM

Understanding the variety of Galactic X-ray transients requires the ability to perform rapid response observations, to catch both the rapid rises, and fast decay of these objects. Swift, although primarily designed for the discovery and follow-up of Gamma-ray bursts, has proven to be very effective at discovery, localization and rapid and long term follow-up of Galactic X-ray Transients. Here we present two different examples of "hard to catch" events where Swift's unique rapid response, low-overhead and broadband sensitive observing capabilities have shed new light on both the rise and fall of X-ray transients events. *Mill-second pulsars:* Swift has monitored the rapid decline to quiescence of accreting millisecond pulsars, such as SAX J1808.4-3658, one of the only millisecond pulsars observed transitioning into quiescence with a sensitive focused X-ray telescope. As these outbursts often end abruptly, only regular monitoring in outburst of the sources will allow us to catch these elusive events, and in the post-RXTE era, only Swift is capable of this task. *Stellar mass black-hole binaries:*

The triggering capabilities of Swift/BAT have allowed us to track the evolution of bright X-ray outbursts from stellar mass black-hole binaries in our galaxy, with example of MAXI J1659-152 shown here, from the beginning of the outburst with new fidelity. Modeling of the X-ray spectrum allows us to track the evolution of the accretion disk in these systems from earlier than previously possible, due to the faster response time to the outburst, and the low energy sensitivity of Swift's X-ray telescope allowing for more sensitive measurements of cooler (inner disk kT<0.5 keV) accretion disks than RXTE. In addition, Swift monitoring of the decay into quiescence of these black hole binaries, can help solve the contentious issue of the nature of the accretion disk in the low/hard state.

153.22 – **The Size And Shape Of The Mass Transfer Nozzle In Eccentric Interacting Binary Star Systems**

Alyssa Mancini[1], C. Haggerty[2], J. Sepinsky[1]

[1]*University of Scranton,* [2]*University of Delaware.*

9:00 AM - 6:30 PM

In order to determine the amount of mass lost from a star which just fills its Roche Lobe, it is imperative to accurately calculate the size of the nozzle -- the area through which the mass flows. This is normally bounded by the equipotential surface where the density of the exponential atmosphere drops by one scale height. When the stars are in an eccentric orbit, Sepinsky et al. (2007) found that the equipotential surfaces defining the peanut-shaped shell ordinarily enclosing the two stars can "open up", no longer enclosing both stars. Furthermore, when attempting to calculate the orbit-variable mass transfer rate for eccentric systems, Haggerty and Sepinsky (2011) discovered that the equipotential surface defining the outer edge of the nozzle may "open up" -- and that this can occur closer to the donor star than its inner Lagrangian point (L1). In such a case, the nozzle is undefined at L1. Here, we develop a method for calculating the effective area of mass transfer by finding the area of the rings bounded at small radii by the Roche Lobe of the donor and at large radii by the equipotential surface. We calculate the area of the ring and its proximity to the L1 point as a function of eccentricity and the binary parameters. We then compare the mass transfer rate calculated for this area to other recent calculations of the mass transfer rate in eccentric binaries.

153.23 – **New Results from the MW Campaign to Observe the 2010/2011 Periastron Passage of the Binary Pulsar System PSR B1259-63/LS 2883**

Aous Abdo[1]

[1]*George Mason University / Naval Research Laboratory.*

9:00 AM - 6:30 PM

PSR B1259-63/SS 2883 is a unique binary system consisting of a 47.7 ms radio pulsar orbiting a massive Be companion star. The interaction between the pulsar's relativistic wind and the Be star's stellar wind around and photon field around periastron is believed to give rise to the unpulsed radio, X-ray, and gamma-ray emissions observed near periastron. Despite designated 3-weeks of observations by EGRET around periastron no GeV gamma-ray emission was observed. We have observed the system in radio, IR, optical, X-ray, GeV, and TeV gamma-ray during the 2010/2011 periastron passage. Our observations of the system in the 0.1-10 GeV energy range around periastron with Fermi showed an unexpected behavior of the system that is not seen at any other wavelength. Our upper limits on GeV emission from this source when it was far from periastron gives a very low gamma-ray efficiency of the pulsar which is an order of magnitude lower than that expected for it's age and distance. We will present results from our MW campaign on the emphasizes on the new findings with Fermi and discuss the possible physical interpretation of the new data.

153.24 – **The Close Binary Fraction of Dwarf M Stars**

Benjamin Clark[1], C. H. Blake[2], G. R. Knapp[2]

[1]*California Institute of Technology,* [2]*Princeton University.*

9:00 AM - 6:30 PM

We describe a search for close spectroscopic dwarf M star binaries using data from the Sloan Digital Sky Survey (SDSS) to address the question of the rate of occurrence of multiplicity in M dwarfs. We use a template fitting technique to measure radial velocities from 145,888 individual spectra obtained for a magnitude-limited sample of 39,543 M dwarfs. Typically, the three or four spectra observed for each star are separated in time by less than four hours, but for ~17% of the stars, the individual observations span more than two days. In these cases we are sensitive to large amplitude radial velocity variations on time scales comparable to the separation between the observations. We use a control sample of objects having observations taken within a four hour period to make an empirical estimate of the underlying radial velocity error distribution and simulate our detection efficiency for a wide range of binary star systems. We find the frequency of binaries among the dwarf M stars with a<0.4 AU to be 3-4% depending on the assumed distribution for the semimajor axis. Comparison with other samples of binary stars demonstrates that the close binary fraction, like the total binary fraction, is a increasing function of primary mass.

153.25 – **An Orbital Radial Velocity Study of PG 1701+359, a Hot Subdwarf B Star with a Cool Main Sequence Companion**

Sandra Liss[1], R. A. Wade[1], B. N. Barlow[1], M. A. Stark[2]

[1]*Pennsylvania State University,* [2]*University of Michigan-Flint.*

9:00 AM - 6:30 PM

Many hot subdwarf B (sdB) stars show composite spectra in which the companion is typically a G or K star. Binary population synthesis (BPS) models show that these systems can be formed by Roche lobe overflow but disagree on the resulting orbital parameters; some predict long periods (years) while others predict much shorter periods (days). Little evidence currently exists to support either theory, but the few observations made to date suggest the periods are not short. At Pennsylvania State University, we conducted observations to measure the orbital parameters of such systems using the Medium Resolution Spectrograph at the Hobby-Eberly Telescope with ~700 m/s precision. Here we present radial velocity (RV) measurements of PG 1701+359, the most well-studied target in our sample. We observed 14 epochs from April 2005 to July 2008 and measured the velocity of the cool companion using cross-correlation techniques. Preliminary RV variations have been detected and indicate the binary has neither a short period nor a large velocity amplitude. This material is based upon work supported by the National Science Foundation under Grant No. AST-0908642.

153.26 – **Radio Stars Observed With Milli-arcsecond Resolution With The Navy Optical Interferometer**

Robert T. Zavala[1], J. J. Sanborn[2]

[1]*US Naval Observatory Flagstaff Station,* [2]*Lowell Observatory.*

9:00 AM - 6:30 PM

A dozen optically bright radio stars provide the link between the HIPPARCOS optical reference frame and cm-VLBI based International Celestial Reference System (ICRS). Many of these stars are binary or hierarchical stellar systems. This requires an orbital solution to correctly register the optical and radio astrometric results. It is surprising to note that significantly different orbital solutions for Algol, one of the HIPPARCOS link stars, existed in the literature. The HIPPARCOS orbit orientation was at odds with the orientation based on observations with the MarkIII and CHARA interferometers. In 2010, Zavala et al. solved the orbital orientation conundrum in favor of the HIPPARCOS orientation, which rested ultimately on the careful work of the late W. Heintz with the long focus Sproul refractor.

As such a thoroughly studied system as Algol could have discrepant orbits in the literature we undertook observations with the Navy Optical Interferometer (NOI, formerly NPOI) to spatially resolve a number of astrometrically important radio stars. Our primary goal is to verify and perhaps improve the orbital elements of these systems. We will present these observations and discuss their astrometric and astrophysical use.

153.27 – **UBVRI Observations And Analysis Of The Solar Type, Total Eclipsing Binary, TYC 3034-299-1**

Danny R. Faulkner[1], N. Blum[1], R. G. Samec[2], A. Jaso[2], P. M. Smith[2], J. White[2], W. Van Hamme[3]

[1]*University of South Carolina Lancaster,* [2]*Bob Jones University,* [3]*Florida International University.*

9:00 AM - 6:30 PM

TYC 3034-299-1 (CVn) is a magnetically active, solar type contact binary and a ROTSE variable. This system was observed as a part of our continuing student/professional collaborative study of interacting binaries. The current UBVRI light curves were taken with the Lowell 0.81-m reflector in Flagstaff on May 10 and May 11, 2010. Four times of minimum light were determined from our observations. They include (with standard errors):

HJD I = 2455326.72754±0.00024, 2455327.713303±0.00025,

HJD II = 2455326.92427±0.00068, 2455327.91256±0.00060.

We also obtained the following timings of minimum light from parabolic fits to the data of Blattler (IBVS number 5699, 2006):

HJD I = 2453382.6915, 2453445.4980, 2453502.3800, 2453515.4154, 2453517.3907,

HJD II = 2453463.4719, 2453515.607.

From these and Nelson's (IBVS numbers 5875 and 5929, 2009) observations, an improved ephemeris was calculated from all the available eclipse timings:

J.D. Hel Min I = 2455326.9244±0.0005 + 0.39500870 ± 0.00000016 d*E.

Our light curve amplitudes are deep for a contact binary, ranging from 0.85 magnitude in U to 0.66 in I. Time of totality of ~7 minutes was detected in the secondary eclipse indicating that this system is a W-type W UMa system (less massive star is hotter). The O'Connell effect ranges from 67 mmag to 36 mmag in U to I, respectively, revealing substantial magnetic activity.

A 5-color simultaneous light curve solution was calculated using the Wilson Code. Our model reveals a dark spot region at longitude 58°. The 18% fill-out and the virtually identical temperatures of the two stars show that the system has nearly reached thermal contact. We performed a q-search over the interval from q = 0.3 to 0.8. The mass ratio is 0.46.

We wish to thank Lowell Observatory for their allocation of observing time and the American Astronomical Society and the Arizona Space Grant for travel support for this

observing run.

153.29 – **New Observations Of The Eclipsing Red Dwarfs In LP133-373**

Todd R. Vaccaro[1], S. Vennes[2], A. Kawka[2], D. Terrell[3]

[1]*Francis Marion University,* [2]*Astronomical Institute AV CR Ondrejov, Czech Republic,* [3]*Southwest Research Institute.*

9:00 AM - 6:30 PM

We have spectroscopically and photometrically observed the low mass eclipsing binary LP133-373 over several years. The new radial velocities have helped refine the physical characteristics of this important system, particularly the mass ratio, which is close to unity. Velocity curves based on measurements of the H alpha emission lines appear to have a larger amplitude than curves made with absorption line measurements, possibly due to the location of active regions. Additional eclipse timings indicate that the orbital period may be changing and the systemic velocity appears to be changing as well.

153.30 – **Fermi/GBM Observations of Torque Switching in Accreting Pulsars**

Mark H. Finger[1], A. Camero-Arranz[1], C. A. Wilson-Hodge[2], P. A. Jenke[3]

[1]*USRA/NSSTC,* [2]*NASA/MSFC,* [3]*MSFC/NPP.*

9:00 AM - 6:30 PM

Torque switching, where an accreting pulsar rapidly switches between alternating intervals of fairly constant spin-up and fairly constant spin-down, has been observed in a number of persistent accreting pulsars. Surprisingly this behavior is see in both Roche-lobe overflow systems where matter flows in a stream from the L1 point, and in systems with wider orbits where matter leaves the companion as a stellar wind. We present observations of torque switching behavior observed with the Fermi Gamma-ray Burst Monitor (GBM) NaI detectors, present searches for correlations between spin-up rate and other source properties, and discuss our results.

153.31 – **Row, Row, Row Your Stokes To The Demon Star**

Janalee Harrison[1], R. T. Zavala[2], D. A. Boboltz[3], D. J. Hutter[2], R. J. Ojha[4], M. T. Richards[5], D. B. Shaffer[6], C. Tycner[7]

[1]*Northern Arizona University,* [2]*US Naval Observatory Flagstaff Station,* [3]*US Naval Observatory,* [4]*GSFC,* [5]*Penn State University,* [6]*Lowell Observatory,* [7]*Central Michigan University.*

9:00 AM - 6:30 PM

Using 7 epochs of data, taken with the VLBA on the Algol system, we will present full polarization images of this eclipsing binary. Data were taken in 2 frequencies (5 and 8 GHz) at various orbital phases, including near the secondary eclipse. We will use the data to produce full polarization images and examine the variation in the polarization properties during a period of relatively quiet radio activity (≤ 15 mJy).

153.32 – **Eclipse Timing Variations of Long-Period Binaries in the Kepler Field**

Jerome A. Orosz[1], D. R. Short[1], G. Windmiller[1], W. F. Welsh[1], Kepler Team

[1]*San Diego State University.*

9:00 AM - 6:30 PM

Prsa et al. (2011) and Slawson et al. (2011) have presented a catalog of eclipsing binaries identified in the first 130 days of Kepler data. The nearly complete and high signal-to-noise light curves give us a tremendous opportunity to measure precise eclipse times and detect deviations from a linear ephemeris, which could be caused by third bodies, among other things. Conroy et al. (2012) present eclipse times for short-period contact systems. We focus here on a subsample of about 1100 detached and semidetached binaries with periods greater than 0.9 days. We discuss the technique used to measure the times of eclipse and show several examples of binaries with large deviations (up to 5 hours) from a linear ephemeris. We give some basic statistical results from the catalog of eclipse timings, and discuss the implications for the rate of close triple star systems.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate. The authors acknowledge support from the

Kepler Participating Scientists Program via NASA grant NNX08AR14G.

153.33 – **New Massive Binaries in the Cygnus OB2 Association**

Rachel Smullen[1], H. Kobulnicky[1], D. Kiminki[1], J. Runnoe[1], G. Long[1], E. Wood[1], I. Ewing[1], C. Vargas-Alvarez[1], M. Alexander[1], A. Bhattacharjee[1]

[1]*University of Wyoming.*

9:00 AM - 6:30 PM

We present results from a continuing radial velocity survey of the massive stars in the Cygnus OB2 Association using spectroscopic data from 2010 June through 2011 November obtained with the 2.3 m Wyoming Infrared Observatory telescope. We find that the early-type star MT267 is a single-lined spectroscopic binary with primary spectral class O8I. The orbital period is 15.03±0.08 days and its eccentricity is near zero. We also present preliminary results for several other candidate binary systems in the Association. This work brings the total number of known massive binaries in Cyg OB2 to at least 21, most of which have nearly complete orbital solutions. Statistics of massive binaries from this program can be used to constrain models of massive star formation and to estimate the rates of energetic phenomena such as supernovae and gamma-ray bursts that form through binary channels.

153.34 – **Demystifying the Confounding Long-Period Eclipsing Binary Epsilon Aurigae - Investigating Clues from its past behavior and possible Stellar Associates**

Cole Johnston[1], E. F. Guinan[1], P. Harmanec[2], P. Mayer[2]

[1]*Villanova University,* [2]*Astronomical Institute of the Charles University, Czech Republic.*

9:00 AM - 6:30 PM

This research is focused on *demystifying* the unusual bright long-period (P = 27.1 years) eclipsing binary ε Aurigae (F0 Ia + disk). We are attempting to cut the “Gordian Knot” to distinguish between two attractive competing models that have been advanced to explain the many unusual properties of this unique binary. According to the "Higher mass" model, the F-supergiant is assumed to be a luminous young (high mass: M > 15 M⊙) F0 Ia star. In this case its huge, cool disk-companion is a proto-planetary disk or an embedded high-mass main-sequence star that has captured a significant mass from the winds of its rapidly evolving companion. In “Lower mass” model the F-supergiant star is assumed to be a post-AGB star (~ 2-3 M⊙) while the large disk companion (of similar mass) is the remnant of a recent mass-losing episode that Post-AGB stars frequently undergo. To distinguish between these models we have followed two approaches. We have investigated the measured brightness of ε Aur over two millennia (using transformed visual measures from Ptolemy and Sufi and others up to the present). We investigated possible brightness changes expected from mass-loss/ exchange events. No significant (larger than ~0.5 mag) changes in brightness were found. We also have estimated the distance to the binary by identifying stars within ~½ degree that appear be associated with the binary. Stars with similar kinematics, color-excesses and ISM lines to ε Aur were found. This association of ε Aur with these possible common cluster stars indicates d ~1.0 +/- 0.15 kpc. In this case, the F-supergiant would have Mv~ -8.0-mag which is appropriate for high-mass F-supergiant but too luminous for a post-AGB object. This research is supported by NSF/RUI Grant AST-1009903.

153.35 – **A Long-Period Benchmark Eclipsing Binary From MARVELS**

Scott W. Fleming[1], S. Mahadevan[1], L. Hebb[2], R. Deshpande[1], A. Roy[1], E. Agol[3], N. De Lee[2], S. Gaudi[4], J. Ge[5], L. Ghezzi[6], J. Pepper[2], R. J. Siverd[2], K. Stassun[2], J. Wisniewski[3], M. Wood-Vasey[7]

[1]*Penn State University,* [2]*Vanderbilt University,* [3]*University of Washington,* [4]*The Ohio State University,* [5]*University of Florida,* [6]*Observatório Nacional/LIneA, Brazil,* [7]*University of Pittsburgh.*

9:00 AM - 6:30 PM

We present a new, detached eclipsing binary (EB) as part of an on-going project to study long-period EBs via spectroscopic binaries (SBs) observed during the MARVELS survey. MARVELS is a multi-object radial velocity (RV) exoplanet search whose primary objective is to homogeneously study exoplanets, but it also observes several hundred SBs as part of its operation. The project starts with SB orbital solutions based on the MARVELS RVs and searches archival photometry to check for eclipses as an efficient means to identify and study long-period EBs. Here we show the first such example of this approach with an EB comprised of a G and K dwarf on an orbital period of 9.67888 days. The eclipsing nature was identified using publically available SuperWASP archival photometry phase-folded on the RV-determined orbital period. Follow-up Echelle observations with the HET telescope measured the fainter component's RVs and provide a measurement of the mass ratio to within 1%. This EB populates a poorly explored region of parameter space where a lack of precise mass and radius estimates exist for K and M dwarfs in EBs with P > 5 days.

153.36 – **WIYN Open Cluster Study: Orbital Solutions for Hard Binaries of NGC 6819**

Katelyn Milliman[1], R. Mathieu[1], A. M. Geller[2], N. M. Gosnell[1], S. Meibom[3]

[1]*University of Wisconsin-Madison,* [2]*Northwestern University,* [3]*Harvard-Smithsonian Center for Astrophysics.*

9:00 AM - 6:30 PM

As part of the WIYN Open Cluster Study (WOCS) we have underway a comprehensive stellar radial-velocity survey of the intermediate-age (2.5 Gyr) open cluster NGC 6819.

Over more than a decade, we have obtained over 12,000 spectra of more than 2000 stars with 11 < V < 16.5. Our sample includes upper main sequence stars, giants, and most potential blue stragglers, as well as some interesting X-ray sources, including a rapidly rotating sub-subgiant.

Given the excellent precision (our error is ≈ 0.4 km/sec) of the radial-velocity

measurements we are able to confidently separate field stars and cluster members. We have detected over 150 velocity variable stars, for which we have more than 75 completed orbital solutions; 51 of these are cluster members. This large sample will allow definition of the NGC 6819's short-period binary population, including mass segregation, the period-eccentricity distribution, and the frequency of the short-period hard-binaries that drive the cluster evolution.

This work was supported by the National Science Foundation through NSF Award AST-0908082.

153.38 – **Transit Timing Variations In Binary Star Systems**

Eric Sansone[1], N. Haghighipour[2]

[1]*Keene State College,* [2]*University of Hawaii - Manoa.*
9:00 AM - 6:30 PM

We present the results of a study of the effect of a stellar companion on the transit timing variations (TTV) of a planetary system. The purpose of our study is to determine the ranges of the orbital elements of a secondary star for which the amplitude of a currently existing TTV is enhanced. We chose the system of Kepler 9 as this system represents the first planetary system detected by the transit timing variation method, and studied its TTVs by considering a hypothetical secondary star in this system. By varying the mass, semi-major axis, and eccentricity of the fictitious binary companion, we tested the stability of the known planets Kepler-9c and Kepler-9b and identified the region of the parameter-space for which the binary planetary system would be stable. We calculated TTVs for the two planets of the system for different values of the orbital elements of the secondary star and calculated its difference with the system's already existing TTVs. Results of our study indicate that the effect of the binary companion is significant only when the secondary star is in a highly eccentric orbit and/or the planets of the system are within the range of Super-Earth or terrestrial sizes. This work was funded by the National Science Foundation in the form of a Research Experience for Undergraduates program at the University of Hawaii at Manoa.

153.39 – **The Realistic Response of Giants Upon Mass Loss Using Non-Adiabatic Models**

Jean-Claude Passy[1], F. Herwig[2]

[1]*American Museum of Natural History, NY, University of Victoria, Canada,* [2]*University of Victoria, Canada.*
9:00 AM - 6:30 PM

Stability of mass transfer is one of the most important ingredient on which binary evolution relies on. In the context of interacting binaries with a donor filling its Roche lobe on a giant branch, it dictates whether a given system will enter a common envelope or not, for instance. The criterion for stability depends on the response of both the donor's Roche radius and its stellar radius. The latter relates to the response of the donor only and can therefore, in most cases, be studied separately.

Previous models relied on modeling giant stars using polytropic stratifications and/or assuming that mass loss happens on a timescale shorter than the thermal timescale of the donor which, consequently, evolves adiabatically. These models yield the paradigm that giants expand upon mass loss so that mass loss starting in semi-detached binaries with a giant donor tends to be unstable. However, this approach is not realistic as it does not capture the response of the superadiabatic layer of the donor which has a local thermal timescale so short that it will readjust on a timescale comparable to the dynamical timescale induced by mass loss.

In this contribution, we are thus trying a different approach using the MESA code with up-to-date macro- and microphysics modules, and follow the donor's response upon high mass loss rates. We find that giants actually barely expand, if at all. This behavior vouches that the adiabatic assumption is void and that more binary systems than previously thought are actually stable against mass transfer.

153.40 – **Fitting Observed Spectra with a Binary Spectral Synthesis Code**

Jonathan Beker[1], N. Hill[2], K. Milliman[2], R. Townsend[2]

[1]*Carleton College,* [2]*UW-Madison.*
9:00 AM - 6:30 PM

We developed the spectral synthesis code Twinsyn to fit observed spectra of double-lined spectroscopic binaries with synthetic spectra derived from a grid of precalculated specific intensities. Twinsyn uses an unreduced chi-square goodness-of-fit statistic and a downhill simplex routine to determine the combination of temperature, surface gravity, rotational, and radial velocity parameters that delivers the best fit between the synthetic and observed spectra. We applied Twinsyn to observations made with the HYDRA multi-object spectrograph on the WIYN 3.5m for the WIYN Open Cluster Study (WOCS) to test its accuracy, and we report on the results here.

This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

153.41 – **Light Curve Solutions of Eclipsing Binaries in the Large Magellanic Cloud**

Meredith L. Rawls[1], M. S. Rao[2]

[1]*New Mexico State University,* [2]*Indian Institute of Astrophysics, India.*
9:00 AM - 6:30 PM

We present model light curves for nine eclipsing binary stars in the Large Magellanic Cloud (LMC). These systems are detached binaries with nearly circular orbits, and were pseudorandomly selected from three of 21 LMC regions in the Optical Gravitational Lensing Experiment II (OGLE-II) survey. We make use of light curves, orbital periods, and binary classification as reported in Wyrzykowski et al. (2003). We present light curve solutions created with the software PHysics Of Eclipsing BinariEs (PHOEBE, Prsa & Zwitter 2005). Each solution has the best-fit mass ratio q, system inclination i, component temperatures T_1 and T_2, and modified Kopal potentials Ω_1 and Ω_2. PHOEBE employs a Nelder & Mead's Simplex fitting method that adjusts all the input parameters to find the best fit to the light curve. Many of the light curves have significant scatter, which can lead to multiple degenerate best-fit solutions, and we discuss what can be done in the future to refine our results, derive global stellar parameters, and place these nine systems in a larger context. We acknowledge the support of the International Research Experience for Students (IRES) program, which is sponsored by the NSF and administered by NSO/GONG.

153.42 – **Measurement Of Separation And Position Angle Of Binary Stars**

Rafael J. Muller[1], J. C. Cersosimo[1], R. A. Rodriguez[1], M. Rosario[1], M. Diaz-rodriguez[1], E. franco[1]

[1]*Univ. of Puerto Rico, Humacao.*
9:00 AM - 6:30 PM

We submit information on position angle and separation of binary star systems. Our data has been obtained at the 31 inch NURO telescope located east of Flagstaff on Anderson mesa. Our data includes binaries obsserved on 2010.

153.43 – **On the Nature of Continuum and Hα Emission Variations of V471 Tau-type Stars**

Caitlin Brecklin[1], V. Strelnitski[2], G. Walker[2], D. Sliski[2], L. Brown[3], M. Muller[2], B. Bosworth[4]

[1]*Michigan State U. & Maria Mitchell Obs.,* [2]*Maria Mitchell Obs.,* [3]*Connecticut Coll. & Maria Mitchell Obs.,* [4]*Mass. Coll. of Art & Design & Maria Mitchell Obs..*
9:00 AM - 6:30 PM

Two close binaries composed of a white dwarf and a red dwarf, V471 Tau and DE CVn, were photometrically monitored with narrowband filters using the CCD-equipped 24-inch and 17-inch telescopes of the Maria Mitchell Observatory. This allowed us to separate the variability of Hα emission from that of the continuum. V471 Tau demonstrated variations in both continuum and line emission similar to what was known from its previous spectroscopy - a double-humped light curve in continuum, with maxima at phases 0.25 and 0.75, and a single-peaked curve in emission, with a maximum at phase 0.5. However, DE CVn showed a double peaked light curve in both the continuum and line emission, which indicates that the line emission is distributed over the surface of the red dwarf similarly to the continuum, not just concentrated in the area illuminated by the white dwarf. Evidence was found for occasional cycle to cycle variations of at least ±5% in both stars. At least one event of emission line flare of approximately 20% was registered in DE CVn, followed by a drop of continuum flux by approximately 15%, on a time scale of 1 day. A possible interpretation involves chromospheric flares in the red companion followed by the development of large dark spots. This project was supported by NSF/REU grant AST-0851892, the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring and the Nantucket Maria Mitchell Association.

153.44 – **Spectroscopic Orbits for Kepler Field of View Binaries**

Rachel A. Matson[1], S. J. Williams[1], D. R. Gies[1], Z. Guo[1]

[1]*GSU.*
9:00 AM - 6:30 PM

We are currently involved in a program to obtain precise photometry of eclipsing binaries with NASA's Kepler Observatory. Using Kepler's unprecedented accuracy and continuous observations, our goal is to search for variations in the eclipse times as a means of finding distant low mass companions to the central binary. In order to constrain the masses of any such companions, precise masses and other parameters of the central binary are needed. We have conducted several observing runs at KPNO and Lowell Observatory to obtain blue spectra of these systems, that when combined with photometry from Kepler, will yield joint radial velocity and light curve solutions. Here we present initial results from our sample of 41 eclipsing binaries, including double-lined radial velocity curves and the orbital fit parameters derived from our spectroscopic observations. In addition, we use Doppler tomography to reconstruct the spectra of the individual components of each binary. These spectra are then fit with synthetic spectra from model atmospheres to determine temperatures, gravities, and metallicities for the central binary. This work was funded in part by NASA grants NNX10AC39G and NNX11AB70G.

153.45 – **The Eccentricity Distribution of Binary Star Systems at the Onset of**

Roche Lobe Overflow

Christopher Culver[1], J. Sepinsky[1], K. Belczynski[2]

[1]*University of Scranton,* [2]*University of Warsaw, Poland.*
9:00 AM - 6:30 PM

While it is commonly assumed that tidal friction will circularize any interacting binary systems prior to the onset of Roche Lobe Overflow (RLO), state-of-the-art population synthesis codes (e.g., StarTrack, Belczynski et al., 2008) have found that this tidal effect may not be strong enough to fully circularize the binary prior to RLO. To investigate this important class of systems, we examine the parameter distribution of systems with a non-zero eccentricity at the onset of RLO. Since there are very few systems observed to undergo eccentric RLO, it is expected that, if it exists, such an eccentric mass transfer phase is short-lived. Using the parameter distribution at the onset of eccentric RLO, we compare the static tidal evolution timescales to the timescales expected via mass transfer effects (see, e.g., Sepinsky et al. 2007b). Furthermore, asynchronous rotation and a non-zero eccentricity can significantly decrease the size of the Roche Lobe, causing RLO to occur even earlier in the binary lifetime than otherwise expect (Sepinsky, Willems, and Kalogera 2007a). Thus, we also update the calculation of the Roche Lobe Radius to include asynchronous rotation and non-zero eccentricity, noting the change in the parameter distribution for the two cases.

153.46 – **High Resolution IR Spectroscopy of D-type Symbiotic Novae**

Kenneth H. Hinkle[1], F. C. Fekel[2], R. R. Joyce[1], P. Wood[3]

[1]*NOAO,* [2]*Tennessee State University,* [3]*Australian National University, Australia.*
9:00 AM - 6:30 PM

We report on time-series high-resolution infrared spectra for five of the six known D-type symbiotic novae. D-type symbiotics are binary systems with a Mira and white dwarf. The spectra map the pulsation kinematics of the Mira and provide the center-of-mass velocity for the Mira. The Mira velocity amplitudes indicate that in the D-type symbiotic novae studied the Miras have masses ~4 solar masses. This is confirmed in one system where the Mira has lithium from hot bottom burning. The white dwarf companions must have evolved from yet more massive progenitors and must be massive. No orbital motion is detected in agreement with previous orbital estimates of periods >100 yrs and semimajor axes ~50 AU. Except during dust forming events Miras in these systems have unobscured spectra short of 1.6 μm even when the mass and period require superwind mass loss. Our results are in agreement with the white dwarf inhibiting dust formation. Longward of 2 μm the spectrum is formed entirely in a warm circumstellar envelope. The long wavelength continuum is possibly formed in the Mira -- white dwarf interacting wind region.

153.47 – **Fragile Binary Candidates in the SDSS DR8 Spectroscopic Archive**

Terry D. Oswalt[1], J. Zhao[1]

[1]*Florida Institute of Technology.*
9:00 AM - 6:30 PM

We present a catalog of 79 very wide fragile binary candidates (projected separations > 10^4 AU) from the SDSS DR8 spectral archive. The pairs were selected based on proper motion, radial velocity, metallcity and photometric parallax criteria. The angular separations of these pairs range from 3 to 250 arc seconds. The peak in the metallicity distribution of these pairs is about -0.5 dex of the solar metallicity. Space motions and the reduced proper motion diagram indicate all these pairs are members of the disk. The chromospheric activity index S_{HK} of each component and member stars of three open clusters (NGC2420, M67 and NGC6791) were measured. The S_{HK} vs. $(g-r)_0$ color relation for most of these binaries is consistent with the trends seen in these open clusters. The ages implied by this relation suggest that fragile wide pairs can survive longer than 8 Gyr. Support for this project from NSF grant AST-0807919 to Florida Institute of Technology is gratefully acknowledged.

153.48 – **Deep GALEX and Optical Images of the R Aqr Symbiotic System**

Joy S. Nichols[1], T. Liimets[2], E. Kellogg[1], R. L. M. Corradi[3], J. Slavin[1]

[1]*Harvard-Smithsonian, CfA,* [2]*Tartu Observatoorium, Estonia,* [3]*Departamento de Astrofisica, Universidad de La Laguna, Spain.*
9:00 AM - 6:30 PM

R Aqr is a symbiotic system with extended and recurring stellar jets and complex surrounding nebular structure. Recent work with Chandra and FUSE have shown that the jets are moving outward with a bulk velocity of up to 600 km/s, with new jets being formed on timescales of years or less. We present new deep GALEX NUV images of the full field of this system. In addition, we have acquired optical narrow-band emission line images in [OI], [OII], and [OIII] that bracket the GALEX data in time. These new datasets allow a direct comparison of the ionization levels in the regions of enhanced emission in both of the wavelength regimes, constraining the temperature and emission mechanisms.

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154 – AGN, QSO, Blazars I

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

154.01 – **The FAST BAL Monitoring Campaign: Multi-epoch Constraints on Quasar Outflows**

Kenza S. Arraki[1], D. Haggard[2], S. Anderson[3], P. Green[4], T. Aldcroft[4]

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9:00 AM - 6:30 PM

Kinetic energy carried by AGN winds and jets may rival radiation as the dominant feedback mechanism regulating galaxy-SMBH co-evolution. Though outflows likely accompany all luminous accretion disks, broad absorption line quasars (BALQSOs) provide the most dramatic astrophysical examples; their massive outflows display P-Cygni profiles that span velocities up to ~0.3c and are visible in the spectra of 15-40% of optically-selected quasars. Spectroscopic variability studies of BALQSOs probe the structure, stability, location, and dynamics of the emitting and absorbing gas near the SMBH and can provide insight into connections between AGN feedback and host galaxy formation and evolution. We report on a multi-year spectroscopic campaign that monitors seventeen BALQSOs (identified originally in the SDSS) using the Fred Lawrence Whipple Observatory's 1.5m telescope's FAST spectrograph. These targets have Chandra X-ray data and have been repeatedly observed with FAST, in regular cadences from one day to two years -- a 6 year cadence is planned for spring 2012. We identify variability in the broad absorption line region, assess its significance, magnitude, and frequency and discuss the constraints these investigations can place on QSO outflows

154.02 – **Spectral Analysis of Radio-Selected Galaxies with the Atacama Cosmology Telescope**

Wenli Mo[1], T. Marriage[1]

[1]*Johns Hopkins University.*
9:00 AM - 6:30 PM

We present results of a spectral index analysis of data collected by the Atacama Cosmology Telescope (ACT) corresponding to locations of radio-selected galaxies detected by the Faint Images of the Radio Sky at Twenty-Centimeters (FIRST) survey. The ACT data is from 148 GHz and 218 GHz observations of an equatorial region overlapping with the Sloan Digital Sky Survey Stripe 82. By binning FIRST sources according to flux, we calculate the ACT flux estimation of each bin using a stacking algorithm. We see a steepening of spectral index between FIRST and ACT frequencies as a function of flux. Also, we do not detect any significant deviation of ACT stacked data when the FIRST sample is limited to galaxies near optically-selected galaxy clusters. Fitting the ACT stacked data at FIRST radio source locations to a power law and using evolution models of active galactic nuclei (AGN) and dusty star forming galaxies (DSFGs) as a function of flux at 1.4 GHz, we estimate an AGN and DSFG spectral index between 148 GHz and 218 GHz.

154.03 – **Which Processes are Responsible for Triggering Active Galactic Nuclei?**

Aden R. Draper[1], D. R. Ballantyne[1]

[1]*Georgia Institute of Technology.*
9:00 AM - 6:30 PM

In order to understand the co-evolution of supermassive black holes and their host galaxies, it is important to understand what mechanisms trigger episodes of active galactic nuclei (AGN). Some researchers argue that AGN activity is triggered by major mergers, while other researchers suggest that secular processes, such as stellar bars or minor mergers, are responsible for fueling AGN. Here, we investigate the importance of secular processes and major mergers for the AGN population at different redshift and luminosity ranges. An evolving major merger rate and theoretical AGN light curve are used to model the hard X-ray luminosity function. By determining which mechanisms are triggering AGN at various redshifts, the processes which drive galaxy evolution at different epochs will be illuminated.

154.04 – **A Ten-Year Photometric Study of Eleven Active Galaxies**

Caroline Anna Roberts[1], K. S. Rumstay[2]

[1]*Sewanee: The University of the South and SARA,* [2]*Valdosta State University and SARA.*
9:00 AM - 6:30 PM

We present multi-wavelength continuum light curves spanning the period 2001 to 2011 for eleven active galaxies. Our sample includes nine Seyfert galaxies (in order of right ascension Mrk 335, Akn 120, Mrk 79, Mrk 704, NGC 4151, NGC 5548, Mrk 817, Mrk 509, and Akn 564) and two radio galaxies (3C-120 and 3C-390.3). These objects were observed in the B, V, R, and I Johnson/Cousins bands with the 0.9-m telescope operated

by the Southeastern Association for Research in Astronomy (SARA) at the Kitt Peak National Observatory. Since May 2010 some have also been observed with the 0.6-m telescope at Cerro Tololo Inter-American Observatory.

These objects exhibit a wide range of variability. Akn 564 has remained constant in luminosity to within ±0.1 mag during the past decade; in contrast 3C-390.3 doubled in brightness between 2002 and 2005, then dimmed. All show a correlation between luminosity (V magnitude) and color (V-R), though with significant scatter.

This work was funded by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872.

154.05 – **Time Dependent Photoionization of Gas Outflows in AGN.**

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[1]*Western Michigan University,* [2]*NASA/Goddard Space Flight Center, Catholic University of America..*

9:00 AM - 6:30 PM

We study the dynamic effects of time varying UV ionizing continuum on radiation bounded photoionized outflows in AGN. We use a 1D hydrodynamics numerical code to verify the predictions of Bautista & Dunn (2010). It is seen that variations in the UV ionizing continuum yield non-equilibrium conditions in the plasma and create supersonic cooling and heating fronts that give the outflows. Thus, large pressure imbalances arise in the cloud, which are compensated by flow motions leading to fragmentation of the wind and dense shells at the leading ends of the outflowing clouds.

154.06 – **X-ray Observations of Broad Absorption Line Quasars**

Leah K. Morabito[1], X. Dai[1], K. M. Leighly[1], G. R. Sivakoff[2], F. Shankar[3]

[1]*University of Oklahoma,* [2]*University of Alberta, Canada,* [3]*GEPI-Observatoire de Paris, France.*

9:00 AM - 6:30 PM

Iron low-ionization broad absorption line quasars (FeLoBALs) are an extremely rare but important subset of quasars. They have the reddest continuum spectra and possibly the largest X-ray absorbing column densities of all quasars. These unique characteristics could be interpreted as either a stage in the normal AGN lifetime, or simply a viewing angle effect on a uniform class of objects. To probe these theories using X-ray absorbing column density, we perform an analysis of Suzaku observations of three FeLoBALs (J0943+5417, J1352+4293, and J1723+5553), detecting J1723+5553 to the 3-sigma significance level in the observed 2-10 keV band. We use the X-ray hardness ratio, as well as the broadband spectral index between the X-ray and UV bands as compared to normal active galactic nuclei (AGN) spectral energy distributions (SED), to constrain the intrinsic column densities in these three objects. We find that the FeLoBALs are consistent with the SED of normal quasars if the intrinsic column densities are $N_H > 7x10^{23}$ cm^{-2} for J0943+5417, $N_H > 2x10^{24}$ cm^{-2} for J1352+4293, and $6x10^{23} < N_H x10^{24}$ cm^{-2} for J1723+5553. At these large intrinsic column densities, the optical depth from Thomson scattering can reach $\tau \sim 6$, which would significantly modulate the UV flux. Since the UV flux is unaffected, our results suggest the X-ray absorbing material is located at a different place from the UV absorbing wind, likely between the X-ray and UV emitting regions. This implies a geometric interpretation. We further calculate the kinetic feedback efficiency for FeLoBALs and find it to be significant, indicating that the outflows are an important feedback mechanism in quasars.

154.07 – **The Evolution With Redshift Of The Seds Of X-ray Selected Sources**

Perry Natalie[1], D. Marchesini[1]

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9:00 AM - 6:30 PM

We match the NEWFIRM Medium-Band Survey (NMBS) K-selected catalogs in COSMOS and AEGIS to the corresponding Chandra X-ray catalogs. We use the photometric redshift code EAZY and a modified template set including Type-1 and Type-2 AGN templates to derive improved photometric redshift estimates. The resulting photometric redshift estimates are excellent, with median in $\Delta z/(1+z)$ of -0.001 and σ_{NMAD}=0.015, with a fraction of catastrophic outliers of 17.5%. Compared to the non X-ray sources, the photometric redshifts are only slightly less accurate, although the fraction of catastrophic outliers in the X-ray sources is a factor of ~4 larger than for the non X-ray sources. We derive rest-frame spectral energy distributions (SEDs) of all X-ray detected sources, exploiting the exquisitely sampled SEDs from NMBS, and study how the rest-frame SEDs of X-ray sources 1) depend on the X-ray luminosity and 2) evolve with redshift. In general, we find little evolution with redshift of the rest-frame SEDs of X-ray detected galaxies. On the contrary, the rest-frame SEDs strongly depend on the X-ray luminosity, with larger emission at both UV-optical and MIR wavelengths in brighter X-ray sources. By decoupling the contributions of the AGN and the host galaxy to the SED, we find that the dependency of the rest-frame SED on X-ray luminosity is consistent with an increasing fraction of Type-1 AGNs with increasing X-ray luminosity at fixed redshift. Finally, for the brightest X-ray sources ($\log(L_X)>44.4$), we find a decreasing fraction of Type-1 AGN with increasing redshift, from $f_{Type1} \sim 67\%$ at z=1.2 to $f_{Type1} \sim 22\%$ at z=3.5, indicative of larger dust obscuration at higher redshifts.

154.08 – **Comparison Of Optical, UV, X-ray, And Gamma-ray Variations Of Selected Blazars In 2011**

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9:00 AM - 6:30 PM

We present multi-wavelength observations of several gamma-ray bright blazars. We combine optical data obtained at Maria Mitchell Observatory on Nantucket Island with space- and ground-based observations carried out with a variety of instruments. These include a number of other optical telescopes, the Fermi Gamma-ray Space Telescope at photon energies of 0.1-200 GeV, the Rossi X-Ray Timing Explorer at 2.4-10 keV, and the Swift satellite at 0.3-10 keV plus optical and UV wavelengths. Three of the observed blazars proved to be particularly active - BL Lac, 3C 279, and PKS 1510-089. BL Lac was of special interest, varying greatly in optical brightness from night to night. In addition, as reported by the VERITAS group, it exhibited a remarkable, short-lived flare at TeV gamma-ray energies on one of the nights. We cross-correlate the variations in the different wavebands in an effort to guide theoretical interpretations of the optical and high-energy emission from blazars.

This project was supported by NSF/REU grant AST-0851892 and by the Nantucket Maria Mitchell Association. The research at Boston University was supported in part by NSF grants AST-0907893, and by NASA through Fermi grants NNX08AV65G and NNX11AQ03G.

154.09 – **Stripe 82 X: Archival XMM Newton- And Chandra-selected AGN In SDSS Stripe 82**

C. Megan Urry[1], S. LaMassa[1], E. Glikman[1], F. Santana[2], B. Lundgren[1], N. Padmanabhan[1], K. Schawinski[1], B. Simmons[1], E. Treister[3], D. Wake[1]

[1]*Yale Univ.,* [2]*U. de Chile, Chile,* [3]*Concepcion University, Chile.*

9:00 AM - 6:30 PM

Multiwavelength surveys have proved very powerful tools for studying galaxies, AGN, and clusters. A “wedding cake" (i.e., tiered) strategy of depth and area samples a wide range of luminosity and redshift, essential for disentangling evolution- and mass-based effects. The study of AGN requires X-rays, and deep X-ray surveys have been a critical part of highly productive multiwavelength surveys like GOODS, COSMOS, Lockman, AEGIS, MUSYC, and Bootes. Most of these surveys cover too small an area to sample rare objects like high luminosity or high redshift AGN, however, so larger surveys are needed to those regimes. Using archival XMM and Chandra data in Stripe 82, along with SDSS spectra and other multiwavelength data for cross-matched sources, we present AGN number counts and the redshift and luminosity distributions. These data constrain the luminosity function and evolution of X-ray-selected AGN in areas of parameter space that have been poorly sampled to date.

154.10 – **Investigating the Influence of the Quasar Spectral Energy Distribution on Emission Lines Using Large-scale LOC Models**

Karen Leighly[1], M. D. P. Hemantha[1], G. Richards[2]

[1]*Univ. of Oklahoma,* [2]*Drexel University.*

9:00 AM - 6:30 PM

Quasar broad lines exhibit several trends, including the Baldwin effect, an anticorrelation between the emission line equivalent width and continuum luminosity. There is suggestive evidence that the Baldwin effect is driven by the spectral energy distribution (SED).

We test this assertion and the efficacy of the locally-optimally-emitting cloud (LOC) model using large-scale Cloudy modeling. We investigate the effect of the SED by constructing a grid of continua in which α_{ox} and the temperature of the UV cutoff are varied independently. We also vary the LOC radial- and density-distribution indices. We constrain the results using three sets of results: the relationship between α_{ox} and CIV equivalent width observed by Wu et al. 2009, the relationship between luminosity and α_{ox} parameterized by Just et al. 2007, and the Baldwin effect results from 19 lines measured in luminosity-sorted quasar composite spectra by Dietrich et al. 2002. We investigate the baseline LOC (column density $\log(N_H)$=23.5) as well as high column density log(NH)=24.5, enhanced abundances (Z=5), and alternative SEDs that have a power law in the EUV rather than an exponential cutoff.

Our preliminary results show that, for the baseline model, the Baldwin effect is explained by a softening of the SED as well as a decrease of the covering fraction at higher luminosities. The radial and density indices are independent of luminosity and lie near the standard values of -1 and -1. In contrast, the high column model explains the Baldwin effect principally as a softening of the SED with no trend in covering fraction. Both the high metallicity and alternative SED models provide poorer fits. The LOC fails to model some emission lines well, and some evidence for two zones is found. Additional results will be described.

This work is funded by NSF AST-0707703.

154.11 – **Black hole masses and Eddington Ratios in a Large Sample of Active**

Galactic Nuclei

Annette Michel[1], D. M. Crenshaw[1]

[1]*Georgia State Univ.*.
9:00 AM - 6:30 PM

We present determinations of black hole masses, bolometric luminosities, and Eddington ratios for a large sample of AGN. We have determined a number of these parameters for the first time using spectroscopic measurements of AGN that we observed with the Lowell Observatory 1.8-m and CTIO 1.5-m telescopes. We compare the various techniques for determining masses of supermassive black holes (reverberation mapping, broad-line region radius vs. luminosity relation, stellar velocity dispersion) to quantify measurement uncertainties and systemic offsets.

154.12 – **The Structure and Energetics of AGN Winds**

D. Michael Crenshaw[1], S. B. Kraemer[2], T. C. Fischer[1], H. R. Schmitt[3], T. J. Turner[4]

[1]*Georgia State Univ.,* [2]*Catholic University of America,* [3]*Naval Research Laboratory,* [4]*University of Maryland Baltimore County.*
9:00 AM - 6:30 PM

We present a study of the structure and kinematics of outflowing winds in nearby active galactic nuclei (AGN). Variability and/or metastable absorption in the nuclear outflows allows us to determine their distances. Determination of the AGN inclinations based on narrow-line region (NLR) kinematics provides our viewing angle with respect to the obscuring torus. Photoionization models of the measured ionic column densities provide the physical conditions (ionization parameters, column densities) in the gas. Combining these parameters with the global covering factor and outflow velocities, we are able to determine the mass outflow rates and kinetic luminosities of the AGN winds. We find that the outflow rates are typically much larger than the accretion rates needed to sustain the AGN luminosities, indicating that most of the incoming fuel get blown out before reaching the inner accretion disk. The kinetic luminosities are often 0.5 to 5% of the bolometric luminosities, suggesting that AGN feedback is important in even moderate luminosity AGN.

154.13 – **First Spitzer Detection Of Dust Reverberation At 3.6 Microns In The Seyfert 1 Galaxy Zw 229-015**

Varoujan Gorjian[1], A. Barth[2], M. Malkan[3], A. Filippenko[4], J. Bloom[4]

[1]*JPL/Caltech,* [2]*UC Irvine,* [3]*UCLA,* [4]*UC Berkeley.*
9:00 AM - 6:30 PM

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, but there have not previously been any definitive measurements of dust reverberation at wavelengths longer than the K band. We have conducted a space based (Spitzer at 3.6 microns) and ground based (V band) monitoring campaign of the Seyfert 1 Zw229-015 and have detected optical/IR reverberation. The cross-correlation between the V-band and 3.6 micron light curves found a strong correlation with a lag of ~15 days, indicating a mean radius of ~15 light-days for the 3.6-micron dust emission region.

154.14 – **Properties of Quasar Close Pairs in the Chandra COSMOS Survey**

Emily C. Cunningham[1], F. Civano[2], T. L. Aldcroft[2], M. Elvis[2]

[1]*Haverford College,* [2]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

Black hole and galaxy co-evolution models predict a phase in which multiple galaxies with active black holes interact, with visible signatures of interaction, and that their activity may be stimulated by tidal disruptions of their ISM. Several studies have been recently conducted to prove the existence of this phase. However, a proper multiwavelength characterization of galaxy pairs is still missing. We present analysis of X-ray emitting galaxy pairs selected in the *Chandra* COSMOS survey. The sources in each pair are within a redshift difference of 0.2 and a projected separation of 10 arcseconds, corresponding to projected physical separations ranging from 27 kpc to 82 kpc. In order to characterize the pairs in the context of the black hole/galaxy co-evolution scenario, we i) fit spectral energy distributions to determine the relative AGN and galaxy contributions, ii) calculated X-ray luminosities and hardness ratios to check the active nature of the black holes and to get a sense of the obscuration levels, iii) examined the morphologies for signatures of mergers, and iv) determined relative velocities from available spectra. Active black holes are present in all of the galaxies, as they are very luminous in the X-ray band, though mildly obscured. In most of the sources, the host galaxy out shines the nuclear light in the optical band. In several lower redshift pairs, where morphological features are more easily observed, we see disturbed morphology and tidal structures, signatures of a first close passage. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

154.15 – **Probing Spectral Properties of Radio-quiet Quasars Searched for Optical Microvariability**

Paul J. Wiita[1], R. Joshi[2], H. Chand[2], A. C. Gupta[2], R. Srianand[3]

[1]*The College of New Jersey,* [2]*ARIES, India,* [3]*IUCAA, India.*
9:00 AM - 6:30 PM

In the context of AGN unification schemes rapid variability properties play an important role in understanding any intrinsic differences between sources in different classes. In this respect any clue based on spectral properties will be very useful toward understanding the mechanisms responsible for the origin of rapid small scale optical variations, or microvariability. Here we have added spectra of 46 radio-quiet quasars (RQQSOs) and Seyfert 1 galaxies to those of our previous sample of 37 such objects, all of which had been previously searched for microvariability. We took new optical spectra of 33 objects and obtained 13 others from the literature. Their H-beta and Mg II emission lines were carefully fit to determine line widths (FWHM) as well as equivalent widths (EW) due to the broad emission line components. The line widths were used to estimate black hole masses and Eddington ratios. Both EW and FWHM are significantly anti-correlated with Eddington ratio; the former trend was strengthened by our new work and the latter was confirmed. However the tendency seen in the smaller sample for sources exhibiting microvariability to be of lower luminosity was not confirmed in our full sample of 83 AGN. Most importantly, this whole sample of EW distributions provides no evidence for the hypothesis that a weak jet component in radio quiet AGNs is responsible for their microvariability.

154.16 – **Blazar Demographics from Multiwavelength Surveys**

Benjamin Elder[1], C. M. Urry[1], T. Brandt[2], L. Maraschi[3]

[1]*Yale University,* [2]*Princeton University,* [3]*INAF, Italy.*
9:00 AM - 6:30 PM

Blazars, which are active galactic nuclei with relativistic jets aligned with the line of sight, provide valuable insight into how black holes produce jets, how the jets are collimated, and how much power jets carry into the interstellar and intergalactic media. They exhibit a wide range of radio through gamma-ray spectral energy distributions (SEDs), leading to strong selection effects in any particular survey. This has contributed to a long-standing controversy about the numbers of blazars as a function of their luminosity. The recent Fermi catalog contains a higher fraction of BL Lac objects than earlier EGRET catalog (which had a higher flux limit), and therefore supports the view that low luminosity blazars are more numerous than high luminosity blazars (contrary to Giommi & Padovani papers in 1994, 1995). We show that associating SED shape with luminosity explains quantitatively the different SED types found in existing radio, X-ray, and gamma-ray blazar samples. In particular, we use simulations to produce mock samples selected at arbitrary wavelengths and flux limits, then compare these predictions to existing blazar samples. In this way we rule out the possibility that radio-luminous, EGRET-detected blazars are the dominant sub-group. Furthermore, we show that the strong negative evolution reported in X-ray-selected blazars, compared to positively evolving radio-selected blazars, is caused by uneven selection (due to SED shape) from a uniformly evolving, underlying population.

154.17 – **Understanding Quasar Variability through Kepler**

Daniel Silano[1], P. J. Wiita[1], A. E. Wehrle[2], S. C. Unwin[3]

[1]*The College Of New Jersey,* [2]*Space Science Institute,* [3]*JPL.*
9:00 AM - 6:30 PM

We are monitoring four flat spectrum radio quasars (blazars) and one powerful radio galaxy, Cygnus A, to search for variability on timescales comparable to the light crossing time of the accretion disk around the central supermassive black hole and the base of the relativistic jet. Kepler's essentially continuous monitoring at 1 min and 30 min cadences allows us to obtain high quality light curves extending for months, something not possible from even semi-dedicated collections of ground based optical telescopes. We can characterize the variability on timescales ranging from several minutes through many days to see if some optical variability in quasars might be due to a bright feature in the accretion disk as it approaches the last stable orbit, or, more likely for blazars, nearly coherent inhomogeneities in the jet, possibly in a helical structure or temporarily dominant turbulent cell. We have analyzed both the raw and "corrected" Kepler data to determine the power spectral densities of the four blazars as well as their structure functions. The principal challenge to our Kepler data analysis is that the automatic pipeline removal of day-to-week-scale drifts also removes real astrophysical brightness variations and so we have concentrated so far on the raw data while we work on better removal of only the instrumental drifts. Our preliminary results on short timescale variations indicate that three of the four blazars showed modest (~15%) variations and relatively slow variability during three months of monitoring, but the fourth also shows many flares (~3%) on several-day timescales, particularly during one quarter. While a visual inspection of this light curve gives a hint of a quasi-period, this is not borne out by the structure function and PDS analyses.

This work is supported by NASA/Kepler grant GO20018.

154.18 – **Testing Evolutionary Models of Giant Radio Sources by Comparing Observations and Simulations**

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9:00 AM - 6:30 PM

The evolutionary process of large, powerful radio quasars and radio galaxies is not well-understood. Pre-existing evolutionary models using simulated catalogs of the radio sky have been compared to observational data in the past, but they were limited by comparatively small real samples. Today, new and larger radio surveys allow more extensive tests that will yield more insight into the nature of these radio sources. We worked with the new observational catalogs from the WENSS, NVSS, and FIRST surveys to determine selection criteria to produce the best sample for such tests. Input parameters were varied in the model code to produce different simulated versions of the radio sky. We compared the observational sample to these "mock catalogs" in order to find the model Universe that best describes the true evolutionary path of radio galaxies.

154.19 – **Towards Better Simple Stellar Population Modeling of Active Galaxies Using Diffusion K-Means and the Southern African Large Telescope**

Gregory Mosby[1], I. Wold[1], A. Sheinis[1], J. Richards[2]

[1]*University of Wisconsin, Madison,* [2]*UC Berkeley.*
9:00 AM - 6:30 PM

We now know that most galaxies have supermassive black holes in their centers, and somewhat unexpectedly, there are relationships--such as the M-sigma relation--between the mass of the central black hole and the velocity dispersion of the host galaxy's stellar spheroid (bulge), even though they lie outside the black hole's influence. Galaxy merger models show reasonable evidence for coevolution of the bulge and black hole since the merging process initiates simultaneous growth of the black hole and galaxy by supplying gas to the nucleus for accretion onto the black hole and triggering bursts of star formation. The merging process truncates the growth of both by removing the gas reservoir via feedback from these processes. However, it's very difficult to observationally test such models on objects at the peak of black hole growth--during the quasar phase, when the central nucleus outshines the host galaxy. But, by using 3-d spectroscopy methods, namely integral field units (IFUs), we have shown that it is possible to successfully recover information about the host galaxy's integrated star formation history that can be used to check merger-induced galaxy evolution predicted by the models. This research focuses on more reliably decomposing AGN host galaxy spectra into simple stellar populations (SSPs) using a statistical method called diffusion k-means. And in effort to advance this topic further with new instrumentation, this research also involves testing and development of the detector for the near infrared arm of the Robert Stobie Spectrograph (RSS) for the newly commissioned 11-meter Southern African Large Telescope (SALT).

154.20 – **The Environments Of The Brightest QSOs At Z ≈ 2.7**

Ryan Trainor[1], C. C. Steidel[1]

[1]*Caltech.*
9:00 AM - 6:30 PM

We present an analysis of the Mpc-scale environments of hyperluminous QSOs (HLQSOs) at z ~ 2.7 using data from the Keck Baryonic Structure Survey (KBSS). Our data include a large sample of spectroscopic galaxy redshifts (Ngal ~ 1500), where each galaxy lies within ~3' of one of 15 of the brightest QSOs at these redshifts. We find that the average HLQSO in our sample is associated in redshift with a significant overdensity in the galaxy distribution with a velocity scale of 300 km/s and a transverse scale of ~25" (~200 proper kpc). We estimate the galaxy-HLQSO cross-correlation function and galaxy autocorrelation function on small transverse scales to compare the halo masses of HLQSOs and star-forming galaxies at these redshifts. We find that the HLQSO host halos have masses log(M/Msun)≈12.4, which is consistent with our dynamical estimates and only ~3x more massive than the galaxy host halos of mass log(M/Msun)≈11.9. We also present recent results from narrow-band survey matched to Ly-α at the redshifts of the HLQSOs. We have spectroscopically confirmed more than 200 Ly-α candidates, which may exhibit fluorescent emission due to the ionizing field of the HLQSOs. Taken together, these measurements will help answer the question of whether HLQSOs inhabit extremely unique environments or are merely observed at special times in an otherwise normal process of galaxy evolution.

154.21 – **Anomalous Trends in Quasar Emission Lines with Accretion Disk Temperature**

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[1]*University of Texas Austin,* [2]*Yale University.*
9:00 AM - 6:30 PM

We compare AGN emission-line properties with theoretical models of the ionizing continua of accretion disks. We infer the characteristic disk temperature from a sample of SDSS AGN based on bolometric luminosity and black hole mass. Observed emission-line intensities show only a slight trend of higher ionization with higher accretion disk temperature, much weaker than predicted. Observed equivalent widths of broad Hβ show a systematic decrease with disk temperature, in contrast to a predicted strong increase based on disk models. We discuss modified radial temperature profiles for the disk that give improved agreement with observation.

154.22 – **Jet Power vs. Black Hole Mass in Blazars: Exploring the Relationship in the Context of the B-Z Mechanism**

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[1]*University of Texas at San Antonio.*
9:00 AM - 6:30 PM

Recently, a tentative negative correlation between jet power and BH mass in a sample of GeV-TeV BL Lac objects(Zhang et al 2011). It was suggested that spin energy extraction could play a significant role in producing the jets and the jets are not purely accretion driven. Broderick et al (2011) recently explored the relationship between jet power and radio core luminosity building on Blanford et al (1979) theoretical work. Using this work we have studied the relationship between radio core luminosity (as a stand in for jet power) and black hole mass and have found a possible positive correlation in a sample of nearby BL Lac objects. The present poster attempts to explore this relationship in the context of the Blanford-Znajek mechanism which predicts jet power increases with black hole mass, spin rate, and accretion rate.

154.23 – **X-Ray Selected AGN in A Merging Cluster**

Joanna M. Taylor[1], D. Norman[2], I. Soechting[3], G. Coldwell[4]

[1]*Indiana University,* [2]*National Optical Astronomy Observatory,* [3]*Oxford University, United Kingdom,* [4]*El Instituto de Ciencias Astronómicas, de la Tierra y del Espacio, Argentina.*
9:00 AM - 6:30 PM

We investigate the X-ray AGN population and evolution in the merging galaxy cluster DLSCL J0522.2-4820 discovered via weak gravitational lensing shear from the Deep Lens Survey (DLS). Since weak lensing shear is dependent only on mass, it does not introduce the biases that typical cluster selection methods do. This cluster is of particular interest due to both its extended multiple X-ray emission peaks and the large number of X-ray point sources identified in the field. We measured the redshifts of X-ray AGN as well as cluster galaxies in order to investigate the 3-dimensional distribution and possible clustering of AGN in galaxy clusters. Of the 125 objects in our sample, 54 are galaxies in the cluster; the cluster redshift is determined to be z=0.2997±0.0096. This agrees well with a previous value of z=0.296±0.001. We identified several broad line AGN at high redshift including a quasar pair at redshift z=1.8. Currently, we have found no X-ray point sources to be within the cluster.

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154.24 – **Iron Depletion Into Grains as a Driver of Fe II Strength in AGNs**

Gregory A. Shields[1]

[1]*Univ. of Texas.*
9:00 AM - 6:30 PM

Active galactic nuclei show a wide range in the intensity of Fe II emission from the broad line region (BLR). We propose that this results from differing degrees of depletion of iron into grains in the low ionization of region of the BLR (Shields et al. 2010, ApJ, 721, 1835). This can occur naturally in a model in which gas flows inward from the "dusty torus" commonly postulated in AGN. As the gas reaches the inner edge of the torus and becomes exposed to the ionizing radiation from the central source, the grain temperature rises. Photoionization models show that, for conventional BLR parameters, the grains reach their sublimation temperature at an intermediate depth in the the Fe II emitting zone. This makes plausible the idea that Fe is restored to the gas phase deep in the partially ionized zone in some objects, giving an extensive zone of strong Fe II emission. In other AGN, the gas traverses most of the partially ionized zone before the grains are destroyed, giving a low gas-phase abundance and weak Fe II. Such a model explains why the BLR radius appears to be smaller than the nominal sublimation radius, because the grains are shielded by the dusty torus as they approach the central

continuum source.

154.26 – **Kiloparsec-scale Jets In The 3cr Lobe-dominated Quasars**

Gareth C. Jones[1], D. H. Hough[1]

[1]*Trinity University.*

9:00 AM - 6:30 PM

We are investigating the physics of kiloparsec-scale jets in a complete sample of lobe-dominated quasars (LDQs). Previously, Bridle et al. (1994, AJ, 108, 766) reported results for 13 of 21 LDQs in a well-defined 3CR complete sample. Here, we add results for the other 8 LDQs, and present new analyses for all 21 sources. No new counterjets were detected, leaving the number of counterjet candidates at 7. The jet/counterjet brightness ratio J ranges from 1.2:1 to >1750:1. Many jets have quasiperiodic trains of knots. The first jet knot is often the brightest. Two key correlations in Bridle et al. are confirmed here: (1) the prominences (normalized brightnesses) of the parsec-scale and kiloparsec-scale jets are highly correlated (99.9% confidence); and (2) the prominence of the kpc jet terminal hot spots is anti-correlated with jet bending angle (99% confidence, but largely dependent on just 3 sources). The first correlation strongly suggests relativistic motion on both pc and kpc scales. The slope of the log prominence correlation (~0.75) is consistent with deceleration on kpc scales, with a range of Lorentz factor centered on ~3. Further, the distribution of J does not require Lorentz factor > 3. The second correlation suggests that highly-bent kpc jets are less able to form powerful hot spots. Future work will explore velocity fields in the kpc jets, and revisit inverse Compton models for their X-ray emission.

This work was supported in part by an AAS Small Research Grant.

154.27 – **Observations and Models of Multiwaveband Variability of Blazars**

Alan P. Marscher[1], S. G. Jorstad[1], V. M. Larionov[2], I. Agudo[3], P. S. Smith[4], A. Lahteenmaki[5], M. Joshi[1], K. Williamson[1], N. MacDonald[1], M. F. Aller[6], H. D. Aller[6]

[1]*Boston Univ.,* [2]*St. Petersburg State Univ.,* [3]*Instituto de Astrofisica de Andalucia, Spain,* [4]*Steward Obs.,* [5]*Metsahovi Radio Observatory, Finland,* [6]*Univ. Michigan.*

9:00 AM - 6:30 PM

Multi-wavelength light curves of bright gamma-ray blazars (e.g., 3C 454.3) reveal strong correlations across wavebands, yet striking dissimilarities in the details. This conundrum can be explained if the major outbursts result from high-amplitude variations in the magnetic field and relativistic electron content in the jet flow, while the faster fluctuations are caused by turbulence in the flow. In the model developed by the author, much of the optical and high-energy radiation in a blazar is emitted near the 43 GHz core of the jet as seen in VLBA images, parsecs from the central engine, as indicated by observations of a number of blazars. This presentation will compare multi-waveband light curves of blazars, compiled by a world-wide collaboration that he leads, with simulated light curves produced by a numerical model that incorporates turbulent plasma - modulated by random fluctuations of the jet flow - crossing standing shocks that compress the plasma and accelerate electrons to highly relativistic energies.

This research is supported in part by NASA through Fermi grants NNX08AV65G, NNX10AO59G, and NNX11AQ03G, and by NSF grant AST-0907893.

154.28 – **Recollimation Boundary Layers in Relativistic Jets**

Susanna Kohler[1], M. C. Begelman[1]

[1]*JILA, University of Colorado and NIST.*

9:00 AM - 6:30 PM

We study the collimation of relativistic jets by the pressure of an ambient medium in the limit where the jet interior has lost causal contact with its surroundings. For a jet with an ultrarelativistic equation of state and external pressure that decreases as a power of distance, $p \sim r^{-n}$, the jet interior will lose causal contact when $n > 2$. The outer layers of the jet gradually collimate toward the jet axis as long as $n < 4$, however, leading to the formation of a shocked boundary layer. Supposing that pressure-matching across the shock front determines the shape of the shock, we study the resulting structure of a hydrodynamic jet in two ways: first by assuming that the pressure remains constant across the boundary layer and looking for solutions to the shock jump equations, and then by constructing self-similar boundary-layer solutions that allow for a pressure gradient across the shocked layer. We find that the constant-pressure solutions can be characterized by four initial parameters that determine the jet shape and whether the shock closes to the axis. Self-similar solutions for the boundary layer can be constructed for which the pressure monotonically decreases inward across the boundary layer, and the behavior of these solutions exhibit a strong dependence on the value of n. We also demonstrate that seeding a jet with a small toroidal magnetic field always results in the pressure becoming magnetically dominated at large radii, and we repeat our boundary-layer calculations taking this magnetic dominance into account. We discuss the insight our models provide into energy dissipation in relativistic astrophysical jets, such as those of AGN and blazars.

154.29 – **Relation Between Events In The Millimeter-wave Core And Gamma-ray Outbursts In Blazars**

Svetlana G. Jorstad[1], A. P. Marscher[1], I. Agudo[2], N. MacDonald[1], T. Scott[1], K. Williamson[1]

[1]*Boston Univ.,* [2]*IAA, Granada, Spain.*

9:00 AM - 6:30 PM

We report results from our program of monitoring 33 gamma-ray detected blazars with the VLBA at 43 GHz. We identify superluminal knots in the jets and determine the epochs when the knots pass through the mm-wave core (the ejection time). We construct a gamma-ray light for each source using photon and spacecraft data provided by the Fermi LAT and identify sources with gamma-ray flares. Comparison of ejection times with times of gamma-ray flares reveals different relations between gamma-ray events and disturbances in the parsec-scale jet: i) a number of γ-ray flares and ejections are simultaneous within the uncertainties (e.g., 3C~273, 3C~454.3. PKS1510-089); ii) several blazars show brightening of the core at mm wavelengths during a gamma-ray flare without the appearance of a new knot (e.g., CTA102); iii) some gamma-ray flares occur after passage of a knot through the core (e.g. 0235+164), and vice-versa; iv) a fraction of the blazars show little or no relation between mm-wave and gamma-ray events. The gamma-ray emission therefore appears to occur in multiple sites in different blazars, and sometimes within a given object. This conclusion has important implications regarding the

inference of the physical conditions under which high-energy emission occurs in the relativistic jets of blazars.

This research was supported in part by NASA grants NNX08AV65G, NNX08AV61G, NNX09AT99G, NNX09AU10G, NNX10AO59G, and NNX11AQ03G, and by NSF grant AST-0907893.

154.30 – **Turbulence, Energy Transfer, And Dissipation In 3d Mhd Simulations Of The Kelvin-helmholtz Instability**

Greg Salvesen[1], K. Beckwith[1], J. B. Simon[1], S. M. O'Neill[1], S. W. Skillman[2], M. C. Begelman[1]

[1]*JILA, University of Colorado,* [2]*CASA, University of Colorado.*

9:00 AM - 6:30 PM

The Kelvin-Helmholtz instability (KHI) is ubiquitous in astrophysical phenomena involving shear layers including accretion disks, jet boundaries, and differentially rotating stars. The linear growth phase of the KHI and its subsequent evolution into turbulence is well-studied; however, the details of energy transfer and spectral structure in the non-linear evolution remain poorly understood. We perform high resolution, 3D simulations of the KHI in the subsonic, weakly magnetized regime using the magnetohydrodynamics code ATHENA and study its development into complete turbulence. We employ a Fourier transfer function analysis to gain insight into energy transfer at different length scales during the non-linear stages of the KHI. In the non-linear regime, the magnetic field amplification is dominated by transfer of kinetic energy into magnetic energy on large spatial scales due to turbulent motions doing work against the magnetic tension force. Large scale magnetic energy is transferred to small spatial scales via a turbulent cascade and is dissipated shortly thereafter at the dissipation scale. Using the transfer function analysis to study numerical dissipation effects, we find that magnetic dissipation exceeds kinetic dissipation by a factor of ~2, which is consistent with prior studies of numerical dissipation in MHD turbulence with ATHENA.

154.31 – **Observations of High Energy Flaring Events in M87 at Multiple Wavelengths from TeV to Radio**

Robert Craig Walker[1], M. Beilicke[2], C. Cheung[3], P. Hardee[4], D. Harris[5], W. Junor[6], H. Krawczynski[2], C. Ly[7], D. Mazin[8], W. McConville[9], M. Raue[10], R. Wagner[11], VERITAS Collaboration, MAGIC Collaboration, H.E.S.S. Collaboration, Fermi-LAT Collaboration

[1]*NRAO,* [2]*Washington University in St. Louis,* [3]*National Aeronautics and Space Administration,* [4]*University of Alabama at Tuscaloosa,* [5]*Harvard-Smithsonian Center for Astrophysics,* [6]*University of California,* [7]*Space Telescope Science Institute,* [8]*IFAE, Spain,* [9]*University of Maryland,* [10]*University of Hamburg, Germany,* [11]*Max-Planck-Institute for Physics.*

9:00 AM - 6:30 PM

M87 contains a several billion solar mass black hole that generates a jet that can be observed across the electromagnetic spectrum. With its relative proximity and large black hole, M87 is arguably the best object in which to study processes in an extragalactic jet on small dynamical scales.

M87 is a source of very high energy (VHE: E>100GeV) ã-rays. That emission shows variability, including significant flares, on time scales as short as a day. Here we report on efforts to associate VHE flares with variability at other bands, where higher resolution observations are possible, to locate the VHE emission region and provide constraints on the VHE emission mechanism.

Clear episodes of VHE flaring have been observed by the atmospheric Cerenkov telescopes VERITAS, MAGIC, and H.E.S.S. in 2005, 2008, and 2010. These flares

each have somewhat different characters in the VHE light curves. Also the activity at other wavelengths showed significant differences. The 2005 event occurred during a large and long lived flare at longer wavelengths in the jet knot HST-1 at 0.86" from the nucleus. HST-1 was quiet during the 2008 and 2010 flares. There was a strong flare at 43 GHz on the radio core seen with the VLBA at the time of the 2008 flare, but not the 2010 flare. The best correlation so far is with X-ray emission from the nucleus. The lack of consistency in light curves and lower frequency activity between the events has prevented reaching clear conclusions so far. However the multi-wavelength analysis places significant observational constraints on the viable emission models.

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

154.32 – **Constraints on Outflow Properties From Mg II in the Broad Absorption-Line Quasar FBQS J1151+3822**

Adrian B. Lucy[1], K. M. Leighly[1], D. M. Terndrup[2], M. Dietrich[3], S. C. Gallagher[4]

[1]*University of Oklahoma,* [2]*National Science Foundation and Ohio State University,* [3]*Ohio State University,* [4]*University of Western Ontario.*

9:00 AM - 6:30 PM

The acceleration mechanism behind quasar outflows is as yet unknown, but constraining the kinetic energy invested in these winds should allow us to discriminate between competing models of their source. To that end, we use new observations of broad absorption-line Mg IIλ2800 in the quasar FBQS J1151+3822 to calculate Mg+ column density in the outflow.

The Mg IIλ2800 apparent optical depth profile bears structural similarities to that of He I*λ10830, suggesting that both lines are produced by the same outflow. Broad Fe II absorption around 2600 Å and blueward reveals that the quasar is an Fe Lo-BAL, and we infer significant iron blending in the high-velocity region of the Mg II line. To account for this blending, we operate under the assumption that the Mg II profile structure approximately mimics that of He I*λ10830, and calculate that Mg+ column density has a lower limit at $\sim 10^{15.0}$ cm^{-2}.

Leighly et al. (2011) used the He I* lines at 10830 and 3889 Å to place broad constraints on the properties of the absorbing gas. Mg II allows us to significantly tighten these constraints; log ionization parameter is now restricted to between -1.4 and -1.3. We furthermore restrict ourselves to a scenario wherein density is between 10^7 and 10^8 cm^{-3}, as justified by Leighly et al. via a dynamical argument and upper limits on Balmer absorption. These preliminary first order approximations constrain kinetic luminosity to between 10^{44} and $10^{44.5}$ ergs/s, absorption-line radius to between 5 and 18 pc, the ratio of kinetic to bolometric luminosity to between 0.2% and 0.6%, mass flux to between 11 and 34 $M_\odot$/yr, and total hydrogen column density to between $10^{21.7}$ and $10^{21.9}$ cm^{-2}.

This work is funded by NSF AST-0707703.

154.33 – **BVR Photometry Of An Inverted-spectrum, Flat-spectrum Radio Source With The Rowan 0.4-meter Telescope**

Erick Guerra[1], A. Diekewicz[1]

[1]*Rowan Univ.*.

9:00 AM - 6:30 PM

Several galaxies have been selected for an exploratory campaign with 0.4-meter telescope atop Science Hall at Rowan University. These galaxies exhibit inverted radio spectra on the basis of fluxes in the GB6 and VLA FIRST catalogs and have SDSS magnitudes in g-band less than 15.5. The results of BVR photometry of one of these galaxies, CGCG 215-024, are presented. These are the first results from an ongoing campaign to expand the function of the observatory atop Science Hall. Efforts to mitigate bulding vibration and light pollution in future work will be presented. The authors would like to acknowledge Ric and Jean Edelman for their gift that funded the 0.4-meter telescope.

154.34 – **Modeling the Spectral Energy Distribution of 3C 279 in the Fermi Era**

Melissa Halford[1], K. Marshall[2], M. Joyce[3], H. Aller[4], M. Aller[4]

[1]*Cornell University,* [2]*Widener University,* [3]*Bucknell University,* [4]*University of Michigan.*

9:00 AM - 6:30 PM

We compare the spectral energy distribution (SED) of the blazar 3C 279 during a gamma ray flare, an X-ray flare and a quiescent period. The SEDs are constructed using data from radio, optical, X-ray and gamma ray bands. We model the emission using a leptonic model with a single spherical emission region moving down the jet of the blazar. This model includes synchrotron self Compton (SSC) emission plus external Compton (EC) radiation from the accretion disk. We find that changes in the SED between the time periods can be explained by changes in the electron energy density and the accretion rate of the central black hole. SSC emission alone is unable to explain the gamma ray emission while adding the EC component accounts for all but the radio data. It is possible that the radio emission comes from a second region farther down the jet. This hypothesis is supported by the long variability timescale of the radio emission as compared to other wavebands as well as the lack of correlation between the radio emission and other parts of the SED. This work was supported by the National Science Foundation's REU program through NSF grant PHY-0552790.

154.35 – **The First Hubble/COS Extreme-Ultraviolet AGN Composite Spectrum**

Matthew L. Stevans[1], J. M. Shull[1], C. W. Danforth[1]

[1]*University of Colorado - Boulder.*

9:00 AM - 6:30 PM

The high-throughput Cosmic Origins Spectrograph (COS) installed on the *Hubble Space Telescope* (*HST*) allows us to obtain high-quality UV spectra of active galactic nuclei (AGNs), many of which serve as background targets for studies of the low-redshift intergalactic medium (IGM). We present a composite spectrum produced by stacking spectra of 22 AGNs with redshifts $0.026 < z < 1.44$, sufficient to explore the far ultraviolet (FUV) and extreme ultraviolet (EUV) ionizing continuum. The composite covers between ~500 - 1800 Å, in the rest-frame, which includes the Lyman continuum of AGNs at $z > 0.245$. The high sensitivity and moderate resolution (20 km/s) of *HST*/COS in the G130M grating allows broad emission lines (Ne VIII, O V, O IV, O III, O II) to be resolved. These broad emission features and others contain much of the ionizing EUV flux. We fit the composite's underlying smooth continuum with a power-law, $F_\nu = A\ \nu^\alpha$ with index α, allowing the extrapolation of the continuum below 500 Å (E > 1.8 ryd). Describing the EUV continuum flux in such a way gives insight into the formation of emission lines, defines the "big blue bump" in the spectral energy distribution of AGNs, and constrains the ionization state of the IGM. We compare our COS-based power-law continuum fit to previous spectral fits from *HST*/FOS (Telfer et al. 2002) and *Far Ultraviolet Spectroscopic Explorer* (*FUSE*) (Scott et al. 2004). This work is supported by the COS-support grant from the STScI (NNX08-AC14G).

154.36 – **Eddington Ratios Of Dust Obscured Quasars**

Mark Lacy[1], T. Urruita[2], S. E. Ridgway[3], A. O. Petric[4], D. Farrah[5], E. Glikman[6], A. Sajina[7]

[1]*NRAO,* [2]*AIP, Germany,* [3]*NOAO,* [4]*Caltech,* [5]*Sussex, United Kingdom,* [6]*Yale,* [7]*Tufts.*

9:00 AM - 6:30 PM

We examine the Eddington ratios of dust reddened quasars selected in the FIRST/2MASS and mid-infrared selected SMIRQS surveys. In the model in which dust-reddened quasars are an early phase in the lifetime of a quasar we would expect the red quasars to show higher than average Eddington ratios, and we are now able to test this. For the 13 objects for which we have host galaxy luminosity estimates from HST imaging we also examine their position on the black hole mass - galaxy luminosity plot compared to local galaxies.

154.37 – **The Optical/Gamma Ray Variability of the Blazar OE 110**

Hugh R. Miller[1], J. Eggen[1], J. Maune[1]

[1]*Georgia State Univ.*.

9:00 AM - 6:30 PM

Significant optical variability has been observed during the past two years for the blazer, OE 110. This included a major outburst in 2010-11 with the maximum brightness detected of R=16.7. This represents a luminous state comparable the baseline state reported by Leacock et al. (1976). The optical outburst was accompanied by a quasi-simultaneous gamma-ray outburst. The historical optical light curves extending back to the mid-1970s show only one prior major outburst. However, only intermittent monitoring of OE 110 from 1975 - present is available due to the generally faint state of this source. Thus many of the reported detections in the past are not the true quiescent state for OE 110, but are peaks of rather modest ~2 - 3 mag. optical flares from a quiescent state near R~22 mag. The results of the more than 30 years optical monitoring of this source is reported in addition to the correlated optical-gamma-ray variations detected during the 2010-2011 flare. This blazer exhibits the second largest range observed for any blazer of ~6.2 mag.

154.38 – **Characterizing Active Galactic Nuclei in the Hard X-Ray Spectrum**

Allison Ashburn[1], L. Winter[2]

[1]*Benedictine College,* [2]*University of Colorado at Boulder.*

9:00 AM - 6:30 PM

Active galactic nuclei (AGN) are supermassive black holes accreting matter at the centers of galaxies. A new way to select AGN is through their very hard X-ray emission. We present the X-ray spectral analysis of newly detected sources from the Swift Gamma-ray burst satellite. We present the Swift XRT and BAT spectra of the uncategorized sources in the BAT 58-month catalog. An X-ray color-color diagram is shown, using the 0.5-2 keV, 2-10 keV, and 14-195 keV bands, to compare these sources with the brightest BAT sources from the Swift 9-month catalog. The newly detected AGN are not heavily obscured, with average column densities of 2.5×10^{21} cm^{-2}. Their average luminosities are 3.5×10^{45} ergs s^{-1}, which is above that of the previously detected AGN, and they are also more distant.

155 – Exoplanet Mission Technologies

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

This poster session features papers which highlight technology progress and plans toward space missions which will detect and characterize low-mass extrasolar planets around nearby stars. The main focus is on techniques for starlight suppression, allowing the direct detection of light from an exoplanet and enabling studies based on photometry and spectroscopy of the planet's light. Progress has been made on several distinct techniques for achieving the needed starlight rejection. The session will also include technology developments toward other kinds of exoplanet measurements, such as microlensing, precision astrometry, and transit spectroscopy.

155.01 – **Technology Development for Exoplanet Missions**

Peter R. Lawson[1]

[1]*JPL.*

9:00 AM - 6:30 PM

This presentation provides an overview of activities funded through NASA ROSES awards for Technology Development for Exoplanet MIssions, part of the solicitation on Strategic Astrophysics Technology. Progress with ongoing efforts are described and the scope of efforts for the 2010 selections are presented.

155.02 – **A Hybrid Lyot Coronagraph for the Direct Imaging and Spectroscopy of Exoplanet Systems: Recent Laboratory Demonstrations and Prospects**

John T. Trauger[1], D. Moody[1], B. Gordon[1], J. Krist[1], D. Mawet[2]

[1]*JPL,* [2]*ESO, Chile.*

9:00 AM - 6:30 PM

We report our best laboratory contrast demonstrations achieved to date. We review the design, fabrication, performance, and future prospects of a hybrid focal plane occulter for exoplanet coronagraphy. Composed of thickness-profiled metallic and dielectric thin films superimposed on a glass substrate, the hybrid occulter provides control over both the real and imaginary parts of a complex attenuation pattern. Together with a deformable mirror for control of wavefront phase, the hybrid Lyot coronagraph potentially exceeds billion-to-one contrast over dark fields extending to within angular separations of 3 λ/D from the central star, over spectral bandwidths of 20% or more, and with throughput efficiencies up to 60%.

We report laboratory contrasts of 3×10-10 over 2% bandwidths, 6×10-10 over 10% bandwidths, and 2×10-9 over 20% bandwidths, achieved across high contrast fields extending from an inner working angle of 3 λ/D to a radius of 15 λ/D. Occulter performance is analyzed in light of recent experiments and optical models, and prospects for further improvements are summarized.

The science capabilities of the hybrid Lyot coronagraph are compared with requirements for the ACCESS mission, a representative exoplanet space telescope concept study for the direct imaging and spectroscopy of exoplanet systems. This work has been supported by NASA's Technology Demonstration for Exoplanet Missions (TDEM) program.

155.03 – **Planet Detection Algorithm using Multiple Images with Independent Speckle Patterns**

Elizabeth Young[1], N. J. Kasdin[1], A. Carlotti[1]

[1]*Princeton University.*

9:00 AM - 6:30 PM

Current observations in the context of exoplanet searches with coronagraphic instruments have shown that one of the main limitations to high-contrast imaging is due to residual quasi-static speckles. Speckles look like the image of a planet, but they have a different spectral behavior and are optically coherent with the star. All speckles are formed from the same coherent source, the star, and are incoherent with the planet. Moving the DM (or other changes to the optical layout) causes interference and therefore changes in the speckle pattern as seen on the camera. Since the planet light does not interfere with the speckles, the image of the planet remains untouched (except that speckles may appear on top of the planet). This fundamental coherence property of the speckles (and incoherence with the planet light) guides us to develop methods to take advantage of a changing speckle pattern to distinguish a planet from a speckle. We present a model of estimating the intensity of a planet given a point spread function (PSF), and assuming an unknown and locally constant background source as well as photon noise. We use this model to develop a planet detection algorithm similar to matched filtering of the PSF. We are extending the work of image analysis from one image to multiple images presuming an independent source of aberrations between images.

155.04 – **Designing Shaped Pupils Without Extraneous Constraints**

Robert J. Vanderbei[1], A. Carlotti[1], N. Kasdin[1]

[1]*Princeton Univ..*

9:00 AM - 6:30 PM

We describe a new way to produce shaped pupils that is orders of magnitude more efficient than what we have done before. As a result, we are now able to produce fully optimized two-dimensional pupil apodizations for which no specific geometric constraints are put on the pupil plane apodization apart from the shape of the aperture itself.

155.05 – **A Reconfigurable Lenslet Integral Field Spectrograph for Detecting and Characterizing Exoplanets from Space**

Marshall D. Perrin[1]

[1]*STScI.*

9:00 AM - 6:30 PM

I present a concept for a simple, compact, reconfigurable lenslet integral field spectrograph as a potential science instrument for space-based characterization of exoplanets. Lenslet IFSes have been universally adopted by ground-based AO high contrast programs because they offer the best wavefront quality of any IFS architecture, significantly better than image slicer designs. However, the complex lenslet-geometry-dependent interlacing of spectra makes it much less straightforward to provide a selection of spectral resolutions through grating or prism interchanges.

Drawing on design heritage from the Keck OSIRIS and Gemini GPI IFSes, I demonstrate that it is in fact possible to design a reconfigurable lenslet IFS with modes that provide for instance (1) R~80 spectra across a 20% bandwidth over a square field of view matched to the wavefront control zone, for survey observations to detect planets, and (2) R~1000 spectra for lenslets covering a reduced field of view (a narrow rectangular subregion of the wide survey FOV), to enable detailed characterization of detected planets. Extension to imaging polarimetry or even spectropolarimetry is also possible. (An alternate mode could provide R~80-100 spectra for a wider spectral bandwidth, say 0.3-1.0 microns simultaneously, but current wavefront control concepts cannot yet provide the required contrast over such a wide band).

This design enables both survey and characterization observations with a single instrument that can be quite compact (optics and mechanisms perhaps 25 x 50 x 50 cm, imaging in both modes onto a single 4096 pixel^2 detector). This simple yet flexible design makes it an excellent match for exoplanet studies from moderate sized (2-4m) telescopes.

155.06 – **The Great Advantage of Larger Apertures for Exoplanet Characterization**

Marc Postman[1], I. N. Reid[1], R. Soummer[1], N. J. Kasdin[2], A. Sivaramakrishnan[1], M. Mountain[1], J. M. Grunsfeld[1]

[1]*STScI,* [2]*Princeton University.*

9:00 AM - 6:30 PM

Large apertures offer major advantages for space-based missions seeking to characterize the atmospheric properties and surface features of terrestrial exoplanets in the Habitable Zones around their host stars. Stellar sample size scales approximately as the cube of the aperture diameter. The effects of a given exozodi background level diminish with increasing aperture. Coronagraph tolerances are substantially relaxed if the inner working angle required corresponds to 4 x lambda/D or more. The distance to which one can measure temporal variations in broadband photometry as the exoplanet rotates is extended substantially as aperture increases. Larger apertures also facilitate the measurement of time-variations in the spectra of exoplanets. We present a summary

of how the above key parameters of exoplanet characterization surveys scale with telescope aperture.

155.07 – **Demonstrating Starshade Performance as Part of NASA's Technology Development for Exoplanet Missions**

N. Jeremy Kasdin[1], D. N. Spergel[1], R. J. Vanderbei[1], D. Lisman[2], S. Shaklan[2], M. W. Thomson[2], P. E. Walkemeyer[2], V. M. Bach[2], E. Oakes[2], E. J. Cady[2], S. R. Martin[2], L. F. Marchen[2], B. Macintosh[3], R. Rudd[3], J. A. Mikula[4], D. H. Lynch[4]

[1]*Princeton Univ.,* [2]*Jet Propulsion Laboratory,* [3]*Lawrence Livermore National Laboratory,* [4]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

In this poster we describe the results of our project to design, manufacture, and measure a prototype starshade petal as part of the Technology Development for Exoplanet Missions program. An external occult 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 for the observatory, greatly relaxing the requirements on the telescope and instrument. In this first two-year phase we focused on the key requirement of manufacturing a precision petal with the precise tolerances needed to meet the overall error budget. These tolerances are established by modeling the effect that various mechanical and thermal errors have on scatter in the telescope image plane and by suballocating the allowable contrast degradation between these error sources. We show the results of this analysis and a representative error budget. We also present the final manufactured occulter petal and the metrology on its shape that demonstrates it meets requirements. We show that a space occulter built of petals with the same measured shape would achieve better than 1e-9 contrast. We also show our progress in building and testing sample edges with the sharp radius of curvature needed for limiting solar glint. Finally, we describe our plans for the second TDEM phase.

155.08 – **Starshade Starlight-Suppression Performance: Modeling and Analysis of Error Sources**

Tiffany M. Glassman[1], S. Casement[1], D. Dailey[1], J. Donovan[1], W. Hurst[1], A. Lo[1], N. Palmer[1]

[1]*Northrop Grumman Aerospace Systems.*

9:00 AM - 6:30 PM

Direct imaging and spectroscopy of terrestrial planets in the habitable zones of nearby stars has been identified as a key goal by the ASTRO2010 Decadal Survey. The starshade is one of two starlight-suppression architectures being considered to meet this goal in the next decade. Key technologies for this concept must be matured in the next several years to demonstrate that this is a feasible way to achieve the science goals. One of the challenges in this technology development effort is creating an error budget for the starshade shape and demonstrating a design that can meet those requirements. This budget must include error sources such as manufacturing accuracy, on-orbit thermal distortion, and on-orbit jitter. We report our latest progress in simulating the effects of these error sources on the starlight-suppression performance, combining them into an error budget for the starshade, and determining the ability of our structural design to meet the budgeted tolerances.

155.09 – **Stray Light Assessment from the Edges of an External Occulter**

L. Suzanne Casement[1], M. R. Flannery[1], T. M. Glassman[1], A. S. Lo[1]

[1]*Northrop Grumman.*

9:00 AM - 6:30 PM

The use of an external occulter has been proposed as one method for the direct detection and spectral characterization of terrestrial planets around other stars, a key goal identified in ASTRO2010. Because of the observational geometry, one of the concerns is stray light from the edge of the occulter that is scattered into the line of sight of the telescope. We have developed a stray light model using physical properties of a realizable occulter edge geometry and material to calculate the resulting stray light. The background signal due to stray light has been calculated for the two telescope architectures adopted for study by the Exoplanet Exploration Program Analysis Group (ExoPAG), a 4 m monolithic and an 8 m segmented mirror design. Comparing the stray light results to the estimated signal levels, we have derived requirements for the occulter edge geometry to meet the sensitivity limits in each of these system configurations.

155.10 – **Laboratory Demonstration of Occulter-Based High Contrast Imaging**

Dan Sirbu[1], E. Cady[2], J. Kasdin[1], R. Vanderbei[1]

[1]*Princeton University,* [2]*Jet Propulsion Laboratory.*

9:00 AM - 6:30 PM

The direct imaging of Earth-like planets in neighbouring solar systems requires generating 10 orders of magnitude in contrast. Using an optimized external occulter, such high levels of contrast suppression can be theoretically achieved using a space telescope. At Princeton, we have designed an experimental testbed where we scaled a 400 mas occulter to fit in the laboratory. We present monochromatic results obtained using a HeNe laser that achieves 10 orders of magnitude of contrast in parts of an annular discovery region in the image plane. We also present mask designs for this testbed that can be used for out-of-band sensing to enable location estimation in the shadow for use in precise formation flight. A second mask design is presented for high contrast imaging that can theoretically achieve 10 orders of magnitude suppression everywhere in the discovery zone and will be verified in the experimental testbed.

155.11 – **A Probe-Class Exoplanet Mission with a Starshade**

Stuart Shaklan[1], D. Spergel[2], N. Kasdin[2], P. Scowen[3], P. Lisman[1], M. Thomson[1], E. Cady[1]

[1]*Jet Propulsion Laboratory,* [2]*Princeton University,* [3]*Arizona State University.*

9:00 AM - 6:30 PM

We present a probe class exoplanet mission concept using an innovative new starshade design that stows in a compact volume enabling a combined launch with a 1m class telescope. Required starshade technology development is limited and low risk, and is presented separately by Kasdin et al. By suppressing the starlight prior to entering the telescope, one eliminates the need for wavefront control and precision optics. We propose use of a commercially available earth imaging telescope with only minor modification. Instrumentation includes a multi-channel photometric camera for exoplanet detection and characterization plus a wide field camera for general astrophysics. Mission simulations show that external occulter agility with conventional chemical propulsion provides repeat visits consistent with orbit determination for multiple exoplanet systems.

155.12 – **Hybrid Schemes for Space-based Planet-Finding**

Dmitry Savransky[1], N. Kasdin[2], S. Shaklan[3], E. J. Cady[3]

[1]*Lawrence Livermore National Laboratory,* [2]*Princeton Univeristy,* [3]*Jet Propulsion Laboratory.*

9:00 AM - 6:30 PM

We present a new class of space-based exoplanet observatories incorporating both internal coronagraphs and external occulters, operating separately, to maximize overall mission science yield. These are shown to be particularly attractive as they can lead to simpler telescope architectures, more highly redundant systems, and can deliver comparable performance with relaxed requirements. Using an advanced mission simulation capability we evaluate the expected performance of these hybrids at multiple telescope scales and with realistic engineering constraints. We present comparisons of the expected science returns for populations of planets including Earth-like planets on habitable-zone orbits and giant planets on wider separation orbits, extrapolated from known populations from doppler surveys. Of particular interest is a hybrid scheme involving an 8 m telescope with an occulter designed for a 4 m aperture, which can be shown to outperform either 'pure' design at that scale.

155.13 – **The EXoplanetary Circumstellar Disk Environments and Disk Explorer**

Glenn Schneider[1], O. Guyon[1], EXCEDE Science Mission and Technology Team

[1]*Univ. of Arizona.*

9:00 AM - 6:30 PM

We present an overview of the EXoplanetary Circumstellar Environments and Disk Explorer (EXCEDE), selected by NASA for technology development and maturation. EXCEDE will study the formation, evolution and architectures of exoplanetary systems, and characterize circumstellar environments into stellar habitable zones. EXCEDE provides contrast-limited scattered-light detection sensitivities ~ 1000x greater than HST or JWST coronagraphs at a much smaller effective inner working angle (IWA), thus enabling the exploration and characterization of exoplanetary CS disks in currently inaccessible domains. EXCEDE will utilize a laboratory demonstrated high-performance Phase Induced Amplitude Apodized Coronagraph (PIAA-C) integrated with a 70 cm diameter unobscured aperture visible light telescope. The EXCEDE PIAA-C will deliver star-to-disk augmented image contrasts of < 10E-8 and a 1.2 lambda/D IWA of 0.14" with a wavefront control system utilizing a 64x64 element MEMS DM and fast steering mirror. EXCEDE will provide 144 mas spatial resolution at 0.4 microns with dust detection sensitivity to levels of a few tens of zodis with two-band imaging polarimetry. EXCEDE is a science-driven technology pathfinder that will advance our understanding of the formation and evolution of exoplanetary systems, placing our solar system in broader astrophysical context, and will demonstrate the high contrast technologies required for larger-scale follow-on and multi-wavelength investigations on the road to finding and characterizing exo-Earths in the years ahead.

155.14 – **Telescopes in Near Space: Balloon Exoplanet Nulling Interferometer (BigBENI)**

Richard Lyon[1], M. Clampin[1], P. Petrone[2], U. Mallik[1], R. Mauk[1]

[1]*NASA/GSFC,* [2]*Sigma Space.*

9:00 AM - 6:30 PM

A significant and often overlooked path to advancing both science and technology for

direct imaging and spectroscopic characterization of exosolar planets is to fly “near space” missions, i.e. balloon borne exosolar missions. A near space balloon mission with two or more telescopes, coherently combined, is capable of achieving a subset of the misison science goals of a single large space telescope at a small fraction of the cost. Additionally such an approach advances technologies toward flight readiness for space flight. Herein we discuss the feasibility of flying two 1.2 meter telescopes, with a baseline separation of 3.6 meters, operating in visible light, on a composite boom structure coupled to a modified visible nulling coronagraph operating to achieve an inner working angle of 60 milli-arcseconds. We discuss the potential science return, atmospheric residuals at 135,000 feet, pointing control and visible nulling and evaluate the state-or-art of these technologies with regards to balloon missions.

155.15 – **High Contrast Imaging With Phase-induced Amplitude Apodization (PIAA)**

Olivier Guyon[1], B. Kern[2], R. Belikov[3], S. Shaklan[2], A. Kuhnert[2], A. Giveon[2], F. Martinache[4], T. Greene[3], E. Pluzhnik[3]

[1]University of Arizona, [2]Jet Propulsion Laboratory, [3]NASA Ames, [4]Subaru Telescope.

9:00 AM - 6:30 PM

The Phase Induced Amplitude Apodization (PIAA) concept uses aspheric optics to apodize a telescope beam for high contrast imaging. The lossless apodization, achieved through geometrical redistribution of the light (beam shaping) allows designs of high performance coronagraphs, ideally suited for direct imaging of exoplanets similar to Earth around nearby stars. The PIAA coronagraph concept has evolved since its original formulation to mitigate manufacturing challenges and improve performance. This is illustrated by the recently developed PIAACMC concept, which can offer sub-lambda/D inner working angle with PIAA optics that are relatively easy to manufacture. We will review the current status of PIAA technology, and show how new designs can allow high science return with small and moderately sized telescopes.

Our group is currently aiming at demonstrating PIAA coronagraphy in the laboratory to 1e-9 raw contrast at 2 lambda/D separation, first in monochromatic light, and then in 10% wide broadband light. Recent results from the High Contrast Imaging Testbed (HCIT) at NASA JPL and the PIAA testbed at NASA Ames will be presented. In parallel with this effort, we are developing and testing new designs with reduced inner working angle. One such system has been recently deployed on the Subaru Telescope as part of the Subaru Coronagraphic Extreme-AO (SCExAO) instrument, and is the first PIAA system used for science observations.

155.16 – **Design And Testing Of A Diamond-turned Four-mirror Phase-induced Amplitude Apodization (PIAA) Coronagraph**

Eric Cady[1], K. Balasubramanian[1], S. Shaklan[1]

[1]Jet Propulsion Lab.

9:00 AM - 6:30 PM

Phase-induced amplitude apodization (PIAA) coronagraphs are a promising technology for imaging exoplanets, with the potential to detect Earth-like planets around Sun-like stars. A PIAA system nominally consists of a pair of mirrors which reshape incident light losslessly. Unfortunately, diffraction limits their performance, and generally they are required to be coupled to an apodizing mask to achieve full performance, which attenuates the planet as well. In addition, these mirrors are highly aspheric and can be very expensive and difficult to manufacture. We propose an alternative: a low-sag four-mirror system with no post-apodization, which maintains high throughput and performance while allowing simplified manufacturing and significantly lower cost. The method of design is given, as well as the progress of the ongoing experimentation.

155.17 – **PIAA Coronagraph Development at NASA Ames: High Contrast Laboratory Demonstration at Inner Working Angles Down to 1.2 l/D**

Ruslan Belikov[1], E. Pluzhnik[1], F. C. Witteborn[1], T. P. Greene[1], D. H. Lynch[1], P. T. Zell[1], O. Guyon[2]

[1]NASA Ames Research Center, [2]University of Arizona.

9:00 AM - 6:30 PM

Coronagraph technology is advancing and promises to enable direct imaging and spectral characterization of extrasolar Earth-like planets with a telescope as small as 1.5m. A smaller Explorer-sized telescope, such as the EXCEDE mission concept, will be capable of seeing debris disks as dim as tens of zodis and potentially a few large planets. As such, EXCEDE will also serve as a technological and scientific precursor for an exo-Earth imaging mission. The Phase Induced Amplitude Apodization (PIAA) provides high throughput and high contrast close to the diffraction limit, enabling aggressive performance on small telescopes. We report on the latest results from a testbed at NASA Ames that is focused on developing and testing the PIAA coronagraph. This laboratory facility is designed to be flexible, operated in an actively thermally stabilized air environment, and to complement collaborative efforts at NASA JPL. For our wavefront control we are using small Micro-Electro-Mechanical-System deformable mirrors (MEMS DMs), which promise to reduce the size of the beam and overall instrument, a consideration that becomes very important for small telescopes. We describe our lab progress and results, which include: the demonstration of 1.9×10^{-8} average raw contrast in a dark zone from 2.0 - 3.4 λ/D and of 1.4×10^{-6} contrast from 1.2-2.0 λ/D (in monochromatic light); the testing of the next-generation reflective PIAA mirror set built by Tinsley and designed for broadband; and finally, discuss our most important past limiting factors as well as expected future ones.

155.18 – **High precision astrometry with a Diffractive Pupil Telescope**

Eduardo Bendek[1], O. Guyon[1], M. Shao[2], M. Ammons[3], S. Shaklan[2], R. Belikov[4], R. Woodruff[5]

[1]University of Arizona, [2]Jet Propulsion Laboratory, [3]Lawrence Livermoore Laboratory, [4]NASA Ames, [5]-.

9:00 AM - 6:30 PM

A concept for high precision astrometry with a conventional wide field telescope is presented, enabling a space telescope to perform simultaneously coronagraphic imaging of exoplanets, astrometric measurement of their orbits and masses, and deep wide field imaging for a wide range of astrophysical investigations. The diffractive pupil telescope uses a regular grid of small sub millimeter spots on the primary mirror coating to produce wide field images containing both a large number of background stars and faint diffraction spikes emanating from the central bright star. The diffraction spikes encode instrumental astrometric distortions due to optics or the detector, allowing precise measurement of the central star against a large number of faint background stars.

With up to a few percent of the primary mirror area covered by the dots, the fraction of the central starlight located in the diffraction spikes is kept sufficiently small to allow full sensitivity deep imaging over the telescope's field of view. Since the dots are regularly spaced, they do not diffract light at small angular separations, and therefore allow full coronagraphic imaging capability. We show that combining simultaneous astrometric and coronagraphic measurements allows improved detection and characterization of exoplanets by constraining the planet(s) characteristics with both measurements. Our preliminary astrometric accuracy error budget shows that sub-micro arcsecond astrometry can be achieved with a 1.4 m diameter telescope, and that astrometric accuracy improves rapidly with telescope diameter. At the University of Arizona, we have constructed a scaled-down testbed to demonstrate the concept with a diffractive pupil and a simulated star field in the laboratory.

156 – LSST

Poster Session – Exhibit Hall – Monday, January 9, 2012, 9:00 AM - 6:30 PM

156.01 – **LSST Probes of Dark Energy: New Energy vs New Gravity**

Andrew Bradshaw[1], A. Tyson[1], M. J. Jee[1], H. Zhan[2], D. Bard[3], R. Bean[4], J. Bosch[5], C. Chang[3], D. Clowe[6], I. Dell'Antonio[7], E. Gawiser[8], B. Jain[9], M. Jarvis[9], S. Kahn[3], L. Knox[1], J. Newman[10], D. Wittman[1], LSST Weak Lensing and LSS Science Collaborations

[1]UC Davis, [2]NAOC, China, [3]SLAC, [4]Cornell, [5]Princeton, [6]Ohio, [7]Brown, [8]Rutgers, [9]Penn, [10]U Pitt.

9:00 AM - 6:30 PM

Is the late time acceleration of the universe due to new physics in the form of stress-energy or a departure from General Relativity? LSST will measure the shape, magnitude, and color of 4×10^9 galaxies to high S/N over 18,000 square degrees. These data will be used to separately measure the gravitational growth of mass structure and distance vs redshift to unprecedented precision by combining multiple probes in a joint analysis. Of the five LSST probes of dark energy, weak gravitational lensing (WL) and baryon acoustic oscillation (BAO) probes are particularly effective in combination.

By measuring the 2-D BAO scale in ugrizy-band photometric redshift-selected samples, LSST will determine the angular diameter distance to a dozen redshifts with sub percent-level errors. Reconstruction of the WL shear power spectrum on linear and weakly non-linear scales, and of the cross-correlation of shear measured in different photometric redshift bins provides a constraint on the evolution of dark energy that is complementary to the purely geometric measures provided by supernovae and BAO. Cross-correlation of the WL shear and BAO signal within redshift shells minimizes the sensitivity to systematics. LSST will also detect shear peaks, providing independent constraints. Tomographic study of the shear of background galaxies as a function of redshift allows a geometric test of dark energy.

To extract the dark energy signal and distinguish between the two forms of new physics, LSST will rely on accurate stellar point-spread functions (PSF) and unbiased reconstruction of galaxy image shapes from hundreds of exposures. Although a weighted co-added deep image has high S/N, it is a form of lossy compression. Bayesian forward modeling algorithms can in principle use all the information. We

explore systematic effects on shape measurements and present tests of an algorithm called Multi-Fit, which appears to avoid PSF-induced shear systematics in a computationally efficient way.

156.02 – **LSST Telescope And Site Developments**

Victor Krabbendam[1], W. Gressler[1], J. R. Andrew[2], J. D. Barr[2], C. F. Claver[1], J. DeVries[2], E. Hileman[2], M. Liang[2], D. R. Neill[2], J. Sebag[2], S. Chandrasekharan[2], A. Vaz[3], O. Wiecha[2], B. Xin[4], LSST Collaboration

[1]NOAO/LSST, [2]NOAO, [3]Harvard University, [4]Purdue Univeristy.

9:00 AM - 6:30 PM

The LSST Project continues to advance the design and development of an observatory system capable of capturing 18,000 deg2 of the sky uniformly in depth in six wavebands over ten years with a 3.5 degree field of view optical system and 3.2 billion pixel camera. The telescope and site engineering designs to support the mission have developed to a preliminary state and construction activities using non-federal funds are proceeding in the areas of mirror fabrication and early site development. Mirror fabrication of each of the mirrors has started using these private funds; an 8.4 m primary (M1) and 5.0 m tertiary (M3) built into a single monolithic substrate and the 3.5 m diameter secondary (M2). Optical fabrication of the unique M1/M3 monolithic mirror has entered final front surface optical processing. Loose abrasive grinding of the M1 surface is complete and has begun on the M3 surface. Polishing will follow and final optical testing is planned in mid 2012. Several critical aspects of the support systems for these mirrors have been prototyped and further risk reduction prototypes are planned. The telescope design has been advanced to include revised baffling that works more efficiently with the dome stray light and wind screen. Design of the dome has been updated to include the positioning of the updated calibration screen. The full summit facility is now at a 90% level of completion; a state sufficient to reveal many of the building details to support operations on the summit including the service and maintenance activities. The active optics wavefront system has been prototyped and shows alignment and mirror surface figure can be maintained to specifications.

156.03 – **LSST Data Products and User Interfaces**

Richard A. Shaw[1], T. Axelrod[2], A. C. Becker[3], S. Bickerton[4], M. Juric[5], J. Kantor[5], S. Krughoff[3], R. H. Lupton[4], S. Van Dyk[6], LSST Data Management and Simulations Teams

[1]NOAO, [2]University of Arizona, [3]University of Washington, [4]Princeton University, [5]LSST Corporation, [6]IPAC, California Institute of Technology.

9:00 AM - 6:30 PM

The LSST will produce the richest sets of astronomical data ever created, which will open up an unparalleled temporal discovery space. The data products will include deep imaging of half of the sky in 6 passbands; catalogs of all detected sources including stars, galaxies, solar system objects; lightcurves of variable objects; and alerts of transient sources that will be generated within a minute of their detection. The LSST Project is currently prototyping a scalable Data Management System (DMS) capable of processing, archiving, and serving these data to the astronomical community. We anticipate that individual investigators and research teams will, during the course of their analysis, generate scientific datasets using data products from LSST (possibly combined with data from other resources) that will be of great value to the LSST community. The LSST Project plans to support these community-based science activities by: providing direct compute and storage resources, use of portions of the LSST software stack, and the development of user and programmatic interfaces that enable the discovery, exploration, and analysis of LSST data products.

In addition to science data products, a number of data products will be generated to assess science quality. Although science data quality assessment will be highly automated, even the limited human interaction required to assess and diagnose problems drives the need to prototype user interfaces that enable efficient data exploration and analysis. Much of this capability is also needed for generating and evaluating calibration products, documenting survey progress, supporting science analysis for users, etc. In this presentation we describe the data products, pipeline processing, and user interface prototypes that have been developed so far to explore algorithms, validate LSST image simulations, and assess output data quality.

156.04 – **Image Quality and Performance of the LSST Camera**

D. Kirk Gilmore[1], S. Kahn[1], A. Rassmussen[1], J. Singel[1]

[1]SLAC/KIPAC.

9:00 AM - 6:30 PM

The LSST camera, which will be the largest digital camera built to date, presents a number of novel challenges. The field of view will be 3.5 degrees in diameter and will be sampled by a 3.2 billion pixel array of sensors to be read-out in under 2 seconds, which leads to demanding constraints on the sensor architecture and read-out electronics. The camera also incorporates three large refractive lenses, an array of five wide-band large filters mounted on a carousel, and a mechanical shutter. Given the fast optical beam (f/1.2) and tight tolerances for image quality and throughput specifications, the requirements on the optical design, assembly and alignment, and contamination control of the optical elements and focal plane are crucial. We present an overview of the LSST camera, with an emphasis on models of camera image quality and throughput performance that are characterized by various analysis packages and design considerations.

156.05 – **Science Opportunities with LSST**

J. Anthony Tyson[1], Z. Ivezic[2], M. Strauss[3], LSST Science Collaborations

[1]UC Davis, [2]U. Washington, [3]Princeton.

9:00 AM - 6:30 PM

The LSST design is driven by four science themes: dark energy and matter, Galactic structure, transient objects, and the Solar System inventory. These and many other science opportunities are described in the LSST Science Book: http://www.lsst.org /lsst/scibook

The LSST will carry out a ten-year very deep imaging survey of 18,000 sq.deg. of the sky in six broad optical bands, with a deep stack reaching r~27.5 (5 sigma, point source). The LSST design, with an 8.4m (6.7m effective) primary mirror and a 9.6 square degree field of view, will allow about 10,000 square degrees of sky to be imaged to an effective depth of r=24.5 every three nights. Each patch of the sky will be visited over 800 times with pairs of 15 sec exposures, opening a new window on the universe: faint time-domain. The resulting petabytes of data will be made available to the US and Chilean communities for scientific investigations ranging from the properties of near-Earth asteroids, to characterizations of dark energy from strong and weak lensing, galaxy clustering, and distant supernovae.

More information is available at http://www.lsst.org

Eleven LSST Science Collaborations are actively laying the groundwork for first light: working on image analysis algorithms and database design, exploring cadence choices, developing commissioning plans, and outlining scientific opportunities. These Collaborations have over 200 members to date, with membership open to the US and Chilean communities via an application process administered by NOAO. Full end-to-end LSST image simulations are a useful resource for exploring science capability.

LSST Science Collaborations:

Supernovae

Weak Lensing

Stellar Populations

Active Galactic Nuclei

Solar System

Galaxies

Transients/variable stars

Large-scale structure and baryon oscillations

Milky Way and Local Volume Structure

Strong Lensing

Informatics and Statistics

156.06 – **Mapping the Stellar Content of the Milky Way with LSST**

John J. Bochanski[1], P. Thorman[2], K. Covey[3], K. Olsen[4], S. Dhital[5], T. C. Beers[4], P. Boeshaar[2], P. Cargile[5], M. Catelan[6], S. Digel[7], P. Guhathakurta[8], T. Henry[9], Z. Ivezic[10], M. Juric[11], J. Kalirai[12], J. Kirkpatrick[13], P. M. McGehee[13], D. Minniti[6], A. Mukadam[10], J. Pepper[5], A. Prsa[14], R. Roškar[15], J. Smith[16], K. Stassun[5], A. Tyson[2], LSST Stellar Populations and Milky Way and Local Volume Science Collaborations

[1]Pennsylvania State University, [2]UC Davis, [3]Lowell Observatory, [4]NOAO, [5]Vanderbilt University, [6]Pontificia Universidad Católica de Chile, Chile, [7]Stanford University, [8]UCO/Lick Observatory, [9]Georgia State University, [10]University of Washington, [11]LSST, [12]STScI, [13]IPAC / Caltech, [14]Villanova University, [15]Institute for Theoretical Physics, Switzerland, [16]Austin Peay State University.

9:00 AM - 6:30 PM

The Large Synoptic Survey Telescope (LSST) will map half of the sky in six filters down to r=27.5 (AB mag; 5-sigma), with typical precision of one percent (0.01 mag). The ten year baseline of the survey will provide about a thousand multi-epoch observations for objects brighter than r=24.5, yielding variability, proper motions and trigonometric parallax measurements for hundreds of millions of stars. The resulting photometric and astrometric catalogs will enable novel and unique investigations, detailing the formation and evolution of the Milky Way's stellar populations, as well as neighboring galaxies. We highlight some of the enabled science studies, including results from the output source catalog derived from simulated LSST images. A few examples of the stellar populations projects will be shown: sampling a census of the MLT population near the solar neighborhood; mapping the structure and stellar metallicity content of the Milky Way's disk and halo; assembling catalogs of eclipsing binaries, subdwarfs and white dwarfs, suitable for measuring fundamental stellar parameters; and measuring the Milky Way's star formation history using stellar ages determined from

gyrochronology and rotation periods, as well as the white dwarf luminosity function. We also highlight the studies enabled by the "Deep Drilling" fields, patches within the LSST footprint that will be imaged at a higher cadence over the course of the survey.

156.07 – **End-to-end Tests of LSST Science Cases with Image Simulations: Rare Astrometric Targets and Ultra-faint Dwarf Galaxies**

Mario Juric[1], D. Monet[2], J. E. Gizis[3], B. Sesar[4], B. Willman[5], M. Geha[6], R. Fadley[5], K. S. Krughoff[7], R. R. Gibson[7], A. J. Connolly[7], R. H. Lupton[8], J. R. Peterson[9], G. J. Jernigan[10], N. M. Silvestri[7], LSST Data Management Team, LSST Image Simulation Team

[1]LSST, [2]USNO, [3]U. Delaware, [4]CalTech, [5]Haveford College, [6]Yale University, [7]U. Washington, [8]Princeton University, [9]Purdue University, [10]U.C. Berkeley.

9:00 AM - 6:30 PM

The LSST is a multi-purpose observatory that will permit unprecedented exploration of a multitude of science topics and hundreds of individual science cases. These range from studies of asteroids in the Solar System to multiple probes of the nature of dark energy (LSST Science Book, Version 2.0, arXiv:0912.0201). The LSST Image Simulation framework provides an opportunity for a quantitative, end-to-end, test of feasibility of many of the proposed studies. Especially suitable are those that only require the capabilities currently present in LSST Data Management software stack, and can be tested with a relatively small number (tens to hundreds) of simulated visits. Here we present two such tests: the recovery of high proper motion astrometric targets based on realistic 10-year simulations of a single LSST sensor, and simulations of observations of four ultra-faint dwarf satellite galaxies embedded in a realistic Milky Way background. The results improve our understanding of LSST software, expected performance of the system, as well as identify areas of research needed to achieve particular science goals.

156.08 – **LSST Image Simulations**

John R. Peterson[1], J. G. Jernigan[2], A. J. Connolly[3], Z. Ahmad[1], J. Bankert[1], D. Bard[4], C. Chang[5], R. R. Gibson[3], D. K. Gilmore[4], E. Grace[1], M. Hannel[1], M. Hodge[1], L. Jones[3], S. M. Kahn[4], K. S. Krughoff[3], S. Lorenz[1], S. Marshall[4], S. Nagarajan[1], E. Peng[1], A. Rasmussen[4], M. Shmakova[4], N. Silvestri[3], N. Todd[1], M. Young[1]

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9:00 AM - 6:30 PM

The precise measurements planned for the Large Synoptic Survey Telescope (LSST) require careful algorithmic studies before the telescope begins operating with its unprecedented image production rate. The LSST Image Simulation group is leading the effort to simulate the LSST system from end-to-end using a high fidelity framework. We first synthesize input astrophysical object catalogs that include stars based on a galaxy model, asteroids, and cosmologically-based galaxy catalogs with morphological parameters. We then use a novel approach to simulate images using a photon Monte Carlo approach. We draw photons from the objects using their spectral energy distributions and propagate those photons through the Universe, atmosphere, telescope, and camera using complex wavelength-dependent photon simulation physics. We describe the simulation framework, and discuss the photon simulation approach that has been used generate millions of high fidelity images.

156.09 – **Exploring Scheduling Algorithms and Analysis Tools for the LSST Operations Simulations**

Catherine E. Petry[1], M. Miller[2], K. H. Cook[3], S. Ridgway[2], S. Chandrasekharan[2], R. L. Jones[4], K. S. Krughoff[4], Z. Ivezic[4], V. Krabbendam[2]

[1]Univ. of Arizona, [2]NOAO, [3]LSSTC, [4]Univ. of Washington.

9:00 AM - 6:30 PM

The LSST Operations Simulator models the telescope's design-specific opto-mechanical system performance and site-specific conditions to simulate how observations may be obtained during a 10-year survey. We have found that a remarkable range of science programs are compatible with a single feasible cadence. The current version, OpSim v2.5, incorporates detailed models of the telescope and dome, the camera, weather and a more realistic model for scheduled and unscheduled downtime, as well as a scheduling strategy based on ranking requests for observations from a small number of observing modes attempting to optimize the key science objectives. Each observing mode is driven by a specific algorithm which ranks field-filter combinations of target fields to observe next. The output of the simulator is a detailed record of the activity of the telescope - such as position on the sky, slew activities, weather and various types of downtime - stored in a mySQL database. Sophisticated tools are required to mine this database in order to assess the degree of success of any simulated survey in some detail. An analysis pipeline has been created (SSTAR) which generates a standard report describing the basic characteristics of a simulated survey; a new analysis framework is being designed to allow for the inter-comparison of one or more simulated surveys and to perform more complex analyses in a pipeline fashion. Proprietary software is being used to interactively explore the database and to prototype reports for the new analysis pipeline, and we are working with the ASCOT team (http://ascot.astro.washington.edu) to determine the feasibility of creating our own interactive tools. The next phase of simulator development is being planned to include look-ahead to continue investigating the trade-offs of addressing multiple science goals within a single LSST survey.

156.10 – **Evaluating LSST Schedule Realizations**

Srinivasan Chandrasekharan[1], S. T. Ridgway[1], K. H. Cook[2], C. Petry[3], R. L. Jones[4], K. S. Krughoff[4], Z. Ivezic[4], LSST Collaboration

[1]National Optical Astronomy Observatory, [2]LSSTC, [3]Univeristy of Arizona, [4]Univeristy of Washington.

9:00 AM - 6:30 PM

How would one quantify and graphically represent the scientific performance of various scientific goals of a survey strategy? A simulated 10-year LSST observing schedule will produce 2.5×10^6 visits and in order to evaluate a simulated schedule, the project, collaborating scientists and team have defined tools called Merit Functions. Each Merit Function evaluates the success of a simulation in acquiring images with properties which characterize a specific parameter. Each Merit Function can be applied to a set of simulations, providing a single numerical value (a Metric) representative of the function and the simulation. The complete set of metric values can be used to quantitatively compare the performance of multiple simulated schedules. At present we are working with 6 groups of Merit functions: Airmass, Astrometry, Early Good Images, Randomization, Solar System, Variables & Transients and Uniformity. The Metrics derived from the Merit functions offer the possibility of comparing simulations quantitatively, within the context of defined functions. However, with dozens of metrics, it is still a challenge to present the results in a format that is both informative and objective. In this poster we show an early attempt to summarize the comparison of metric sets graphically.

156.11 – **The NOAO Transient Sky Project**

Thomas Matheson[1], NOAO LSST Science Working Group

[1]NOAO.

9:00 AM - 6:30 PM

Modern time-domain surveys have demonstrated that finding variable objects is relatively straightforward. The problem now is one of selecting and following up discoveries. With the Large Synoptic Survey Telescope on the horizon, the magnitude of the problem will inevitably increase. One way to prepare for the coming onslaught is to have realistic estimates of the numbers of potential detections so that resources can be developed to meet that need. The NOAO Transient Sky Project seeks to characterize the variable sky in terms of types of objects, distribution on the sky, and distribution in apparent magnitude. Using Solar System and Galactic models, we can predict numbers of Solar System and some Galactic transient sources for any given pointing of a time-domain survey, or estimates of the numbers per night. We continue to add other transient sources, both Galactic and extragalactic, to our model.

156.12 – **How Many Galactic Variables will LSST Detect?**

Stephen T. Ridgway[1]

[1]NOAO.

9:00 AM - 6:30 PM

The Large Synoptic Survey Telescope operational plan includes release of alerts, within 60 seconds, for all sources that are found to have varied from template images. The number of these alerts has been variously estimated at 10^5 to 10^6 per night. Many of these alerts will be for galactic variable stars. The number of galactic variables detected can be estimated from the bottom up, with known statistics for each variable type. Here we take a top-down approach. A galactic synthesis model (Robin et al, 2003) is used to generate a fictitious but statistically valid star list for a given pointing. Analysis of the first 3 months of the Kepler survey (Ciardi et al, 2011) is used to characterize the probability of stellar variability by spectral type, as a function of variability amplitude. With this model and the LSST survey parameters, it is possible to predict that LSST will alert on $\sim 10^5$ galactic variable stars each night at intermediate galactic latitude. Most of these sources will be known variables after a few months of operation.

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102 – Early-type Galaxies

Oral Session – Room 17B – Monday, January 9, 2012, 10:00 AM - 11:30 AM

102.01 – **Probing Minor-merger-driven Star Formation In Early-type Galaxies Using Spatially-resolved Spectro-photometric Studies**

Sugata Kaviraj[1], M. Crockett[2], J. Silk[3], R. W. O'Connell[4], B. Whitmore[5], R. Windhorst[6], M. Cappellari[2], M. Bureau[2], R. Davies[2]

[1]*Imperial College London and University of Oxford, United Kingdom,* [2]*University of Oxford, United Kingdom,* [3]*Johns Hopkins University,* [4]*University of Virginia,* [5]*Space Telescope Science Institute,* [6]*Arizona State University.*
10:00 AM - 10:10 AM

Recent studies that leverage the rest-frame ultraviolet (UV) spectrum have revealed widespread recent star formation in early-type galaxies (ETGs), traditionally considered to be old, passively-evolving systems. This recent star formation builds ~20% of the ETG stellar mass after z~1, driven by repeated minor mergers between ETGs and small, gas-rich satellites. We demonstrate how spatially-resolved studies, using a combination of high-resolution UV-optical imaging and integral-field spectroscopy (IFS), is a powerful tool to quantify the assembly history of individual ETGs and elucidate the poorly-understood minor-merger process. Using a combination of WFC3 UV-optical (2500-8200 angstroms) imaging and IFS from the SAURON project of the ETG NGC 4150, we show that this galaxy experienced a merger with mass ratio ~1:15 around ~0.9 Gyr ago, which formed 3% of its stellar mass and a young kinematically-decoupled core. A UV-optical analysis of its globular cluster system shows that the bulk of the stars locked up in these clusters likely formed ~6-7 Gyrs in the past. We introduce a new HST-WFC3 programme, approved in Cycle 19, which will leverage similar UV-optical imaging of a representative sample of nearby ETGs from SAURON to study the recent star formation and its drivers in unprecedented detail and put definitive constraints on minor-merger-driven star formation in massive galaxies at late epochs.

102.02 – **The UV Upturn In Elliptical Galaxies And Environmental Effects**

Sukyoung Yi[1], J. Lee[1], Y. Sheen[1], H. Jeong[2], H. Suh[1], K. Oh[1]

[1]*Yonsei Univ., Korea, Republic of,* [2]*KASI, Korea, Republic of.*
10:10 AM - 10:20 AM

It is suspected that the ultraviolet (UV) upturn phenomenon in elliptical galaxies and extended horizontal-branch stars in globular clusters have a common origin. An extremely high abundance of helium (Y~0.4) allows for a working hypothesis, but its origin is unclear. Peng & Nagai (2009) proposed that primordial helium sedimentation in dark haloes over cosmic timescales may lead to extreme helium abundances in galaxy cluster centers. In this scenario UV upturn should be restricted to brightest cluster galaxies (BCGs) only. This is a clear and testable prediction. We present tests of this hypothesis using galaxy clusters from Yoon et al. (2008) that were detected by both the Sloan Digital Sky Survey and the Galaxy Evolution Explorer Medium Imaging Survey. Using a new UV classification scheme based on far-UV, near-UV, and optical photometry we found only 5% of cluster elliptical galaxies show a UV upturn, while 27% and 68% are classified as "recent star-formation" and "UV-weak" ellipticals, respectively. The data reveal a modest positive dependence of the UV upturn fraction on galaxy velocity dispersion, which is in agreement with the earlier findings of Burstein et al. (1988) and possibly with the helium sedimentation theory. However, we do not see any dependency on rank or luminosity of galaxies. Besides, BCGs do not show any marked difference in UV upturn fraction or strength, which is inconsistent with the prediction. We conclude that the aforementioned helium sedimentation theory and its inferred environmental effects are not supported by the available data.

102.03 – **Detection of Ongoing, Low-Level Star Formation in Nearby Ellipticals**

Alyson Ford[1], J. N. Bregman[1]

[1]*University of Michigan.*
10:20 AM - 10:30 AM

Small amounts of star formation in early-type galaxies are suggested by several results: surprisingly young ages from optical line index dating, cooling X-ray gas, and mid-IR dust emission. Low levels of star formation have previously been difficult to detect, but using UV imaging from the Hubble Space Telescope's Wide Field Camera 3 (WFC3), we have identified individual young stars and star clusters in four nearby ellipticals by their UV colors and magnitudes. Ongoing, low-level star formation is detected in all four galaxies, including three ellipticals that have previously exhibited potential signposts of star forming conditions (NGC 4636, NGC 4697, and NGC 4374), and our “control” galaxy, the typical "red and dead" elliptical NGC 3379. The detected current star formation rates in our closest targets, where the census of young stars and clusters is reasonably complete, are between 3E-5 and 8E-5 M⊙/yr.

102.04D – **Who Said Red And Dead? A Gas Menagerie In Local Early-type Galaxies**

Katherine A. Alatalo[1], T. A. Davis[2], L. M. Young[3], C. Heiles[1], L. Blitz[1], M. Bureau[4], K. Nyland[3], M. Cappellari[4], E. Emsellem[2], D. Krajnović[2], R. M. McDermid[5], ATLAS3D Collaboration

[1]*UC, Berkeley,* [2]*European Southern Observatory, Germany,* [3]*New Mexico Tech, NRAO,* [4]*Oxford University, United Kingdom,* [5]*Gemini Observatory.*
10:30 AM - 10:50 AM

Molecular gas in early-type galaxies (ETGs) has been shown to be far more common than previously expected. In fact, at least 22% (60/259) contain a significant reservoir of molecular gas. To gain insight into the presence and prevalence of this unexpected gas, it is important to understand its timeline, where it originated, how it is evolving, and how long it will remain. Imaging of the molecular gas is essential addressing these issues. We present the CO maps of 31 ETGs in the ATLAS3D survey, imaged with the Combined Array for Research for Millimeter Astronomy (CARMA), the largest systematic survey of the cold ISM in ETGs to date. ETGs feature a rich variety of gas configurations, including disks, extended molecular rings, spiral arms, and disrupted merger remnants. The menagerie observed by CARMA illustrates that the various paths molecular gas takes in ETGs is complex and nuanced, ranging from objects undergoing an interaction to those with purely quiescent origins. We also detail the rich molecular story of NGC1266, and how it plays host to an AGN-driven molecular outflow, quenching its star-forming material within the next 100 Myr. The ATLAS3D survey is a complete volume-limited survey of 259 massive (Mgal > 6e9 Msuns) ellipticals and lenticulars within 42 Mpc. It provides the best constraints on the formation and evolution of local early-type galaxies through multi-wavelength studies. Support for CARMA construction was derived from the states of California, Illinois, and Maryland, the James S. McDonnell Foundation, the Gordon and Betty Moore Foundation, the Kenneth T. and Eileen L. Norris Foundation, the University of Chicago, the Associates of the California Institute of Technology, and the National Science Foundation. Ongoing CARMA development and operations are supported by the National Science Foundation under a cooperative agreement, and by the CARMA partner universities.

102.05D – **Elliptical Galaxy Kinematics and Dark Matter Halos with VIRUS-P**

Jeremy Murphy[1], K. Gebhardt[1], J. E. Greene[2], G. Graves[3]

[1]*University of Texas, Austin,* [2]*Princeton,* [3]*University of California, Berkeley.*
10:50 AM - 11:10 AM

Dark matter is now ubiquitous in galactic astronomy, yet our understanding of both its extent, shape, and influence on the evolution of galaxies remains poorly understood. In the case of giant elliptical galaxies, which typically reside in dense environments and accumulate their mass via a range of processes, yet maintain tight scaling relations between a wide variety of their parameters, our understanding of the dizzying variety of mechanisms involved is a work in progress. To this end I will discuss an ongoing project being carried out at McDonald Observatory using the VIRUS-P integral field spectrograph to characterize the dark matter halos, stellar anisotropy and stellar abundance patterns of the most massive galaxies in the local universe from measurements of integrated stellar light. We have observed 23 giant elliptical galaxies over a range of environments. Seven of the 23 galaxies in our data set our Brightest Cluster Galaxies (BCG). I will present spectra and kinematics for a subsample of the survey. Three-integral axisymmetric dynamical modeling, based on Schwarzschild's method of orbit-superposition, will be presented for 3 BCGs in our sample (NGC 4472, M87 and NGC 2832). For the case of M87 we have data extending to 5 effective radii which allows for a direct comparison between stellar kinematics and other mass tracers typically used at large radial distances where the stellar light has historically been too faint to extract reliable kinematics. The mass distribution of all 3 of these galaxies is dominated by their dark matter halo at large radii. The degree of stellar radial and tangential anisotropy of the stars is returned from the modeling process. I will discuss how the stellar anisotropy, combined with stellar abundance patterns from measurements of the Lick indices, can be used to infer how the most massive galaxies accumulated their mass over time.

102.06 – **A Multi Wavelength Survey of Early-Type Galaxies**

Yuanyuan Su[1], J. Irwin[1]

[1]*University of Alabama.*
11:10 AM - 11:20 AM

The emission weighted metal abundance of the hot gas in early-type galaxies are known to be surprisingly lower than the theory expectation and varies between galaxies of similar optical luminosities, which predicts some missing factor in the enrichment process. With Chandra, XMM-Newton and Suzaku, we studied more than 40 early-type galaxies with the span of X-ray luminosities up to 4 orders of magnitude. We find some correlations in relationships between LX, LK, temperature and abundance, with a large scatter and a dichotomy between X-ray faint and X-ray bright galaxies. We compared the measured abundance of X-ray faint galaxies and their neutral gas mass to examine the scenario that the measured low abundance of X-ray faint galaxies is the result of the dilution of remaining hot gas by such pristine neutral gas.

102.07 – **Carnegie-Irvine Galaxy Survey: Structure of Nearby Elliptical Galaxies from 2-Dimensional Image Decomposition**

Song Huang[1], L. C. Ho[1], C. Y. Peng[1], Z. Y. Li[2], A. J. Barth[3]

[1]*Carnegie Observatories,* [2]*Shanghai Observatory, China,* [3]*University of California, Irvine.*
11:20 AM - 11:30 AM

Despite tremendous recent observational progress at both high and low redshifts, there are still many open questions regarding the formation and evolution of elliptical galaxies. A detailed examination of the photometric structure of the nearest and brightest elliptical galaxies can give useful clues to the dominant evolutionary pathway of these systems. Despite the wealth of details afforded by modern images, the structure of elliptical galaxies is still often simplified by single Sersic model fits, usually done in one dimension.

We conduct a detailed structural decomposition of a complete, well-defined sample of 94 bright elliptical galaxies, selected from the Carnegie-Irvine Galaxy Survey (CGS) of 605 bright, nearby galaxies in the sourthern hemisphere. The images are deep and were taken under good seeing conditions from Las Campanas Observatory. Our analysis makes use of the two-dimensional fitting code GALFIT. We find evidence that a large fraction (2/3) of these local ellipticals are well fit by a two-component model, each of which can be described by a Sersic function. The secondary component is either a compact central component or a very extended outer component. We examine the impact of these results on the scaling relations of elliptical galaxies, and discuss their implications for different galaxy formation scenarios.

103 – HEAD: Explosive Autopsy: What Do Remnants Tell Us About Core-Collapse Supernovae?

Special Session – Room 18B – Monday, January 9, 2012, 10:00 AM - 11:30 AM

The process by which massive stars transition from a gravitationalcollapse of the stellar core to a supernova explosion is nowunderstood to be an inherently multidimensional phenomenon. Numerical simulations now consistently show that the shock wave emanating from the collapsed core is no longer spherical. Moreover, the interaction of this aspherical shock with the stellar envelope introduces even more dynamical instability, resulting in large-scale inhomogeneities within the ejecta thrown out by the explosion. Such inhomogeneities are very difficult to study in supernovae themselves, but become accessible to observation hundreds to thousands of years later, in supernova remnants. As our understanding of the core-collapse mechanism has advanced, so have our observational capabilities: X-ray imaging and spectroscopy of remnants of core-collapse supernovae can now provide a detailed look at the spatial distribution, composition, and dynamics of the ejected material. This session aims to bring these two advancing fields together in search of one cohesive theory of core-collapse supernovae. Do the structure, composition, andmacroscopic mixing predicted by supernova simulations match the observations of young core-collapse remnants like Cassiopeia A?

103.01 – **Investigating the Deaths of Massive Stars**

William R. Hix[1]

[1]*Oak Ridge National Laboratory.*

10:00 AM - 10:22 AM

Marking the death of a massive star, and the birth of a neutron star or black hole, core collapse supernovae bring dramatic change to their circumstellar environment through their ejecta. Carrying 10^51 ergs of kinetic energy and a rich-mix of newly synthesized atomic nuclei, the spreading ejecta provides hints about the inner workings of the supernova itself, revealing features originally hidden deep inside the stellar core. We will discuss our emerging understanding of the convectively unstable, neutrino-driven explosion mechanism, highlighting the imprint it leaves on the morphology and isotopic composition of the ejecta. Ultimately, observations of such features, in supernovae and their remnants, will provide the confirmation of the simulations and verification of our understanding.

103.02 – **The First Three Months of a Core Collapse Supernova: Multidimensional Hydrodynamic Models**

Tomasz Plewa[1], A. Gawryszczak[2], K. Kifonidis[3], A. Odrzywolek[4]

[1]*Florida State University,* [2]*Nicolaus Copernicus Astronomical Center, Poland,* [3]*MPA, Germany,* [4]*Jagiellonian University, Poland.*

10:22 AM - 10:44 AM

We study the hydrodynamic evolution of a non-spherical core-collapse supernova in three-dimensions. We begin our study from the moment of shock revival - taking into account neutrino heating and cooling, nucleosynthesis, convection, SASI-type instabilities of the supernova shock - and continue for the first 3 months after the explosion when the expanding flow becomes homologous and the ejecta enter the early supernova remnant phase. We observe the growth and interactions of the fluid flow instabilities, aided by radioactive heating at late times, resulting in an extensive mixing of the heavy elements throughout the ejecta. Analysis of our results provides information to what degree supernova remnants preserve memory about the explosion phase.

103.03 – **A Mass and Density Estimate for the Unshocked Ejecta in Cas A based on Low Frequency Radio Data**

Tracey DeLaney[1], N. Kassim[2], L. Rudnick[3], K. Isensee[3]

[1]*West Virginia Wesleyan College,* [2]*Naval Research Laboratory,* [3]*University of Minnesota.*

10:44 AM - 11:06 AM

One of the key discoveries from the spectral mapping of Cassiopeia A with the Spitzer Space Telescope was the discovery of infrared emission from cold silicon- and oxygen-rich ejecta interior to the reverse shock. When mapped into three dimensions, the ejecta distribution, including both hot and cold ejecta, appears quite flattened. On the front and back sides of Cas A, the Si- and O-rich ejecta have yet to reach the reverse shock while around the edge these layers are currently encountering the reverse shock giving rise to the Bright Ring structure that dominates Cas A's X-ray, optical, and radio morphology. In addition to morphology, the density and total mass remaining in the cold, unshocked ejecta are important parameters for modeling Cas A's explosion and subsequent evolution. The density estimated from the Spitzer data is not particularly useful (upper limit of 100/cm^3), however the cold ejecta are also observed via free-free absorption at low radio frequencies. Using Very Large Array observations at 330 and 74 MHz, we have a new density estimate of 2.3/cm^3 and a total mass estimate of 0.44 M_solar for the cold, unshocked ejecta. Our estimates are sensitive to a number of factors including temperature and geometry but we are quite pleased that our unshocked mass estimate is within a factor of two of estimates based on dynamical models. We will also ponder the presence, or absence, of cold iron- and carbon-rich ejecta and how these affect our calculations.

103.04 – **Clues to Core-Collapse Supernovae from their Remnants**

Una Hwang[1]

[1]*NASA's GSFC.*

11:06 AM - 11:28 AM

I will survey results for X-ray emitting remnants that offer clues to core-collapse supernova explosions, placing special emphasis on Cassiopeia A, which is currently the best candidate for this purpose by virtue of its proximity, youthful age and extensive pre-supernova mass loss. Consideration will be given to the observed maps of the X-ray emitting ejecta, the estimated ejecta masses, and the measured dynamics of the ejecta, as well as implications for the synthesis of Fe during the explosion and the related question of the natal kick imparted to the neutron star.

104 – Variable Stars

Oral Session – Room 19B – Monday, January 9, 2012, 10:00 AM - 11:30 AM

104.01 – **Starspot Imaging Using Kepler Photometry**

Rachael M. Roettenbacher[1], M. Still[2], R. O. Harmon[3], T. Barclay[2]

[1]*University of Michigan,* [2]*NASA Ames Research Center,* [3]*Ohio Wesleyan University.*

10:00 AM - 10:10 AM

A large number of stellar objects in the Kepler field of view have been found with quasi-coherent photometric structure. The variations are likely due to photospheric starspots. Assuming that the observed structure is the result of starspots, the quasi-coherent nature of the objects' light curves may result from a combination of differential rotation and starspot evolution. Using multi-year, milli-magnitude precision, uninterrupted 30-minute cadence Kepler data, we map stellar surfaces of several Kepler stars using a light-curve inversion algorithm. We measure starspot filling factors, differential rotation and starspot migration and growth, and starspot longevity with the goal of identifying possible solar-like magnetic cycles. For example, in two years of data we identify over twenty distinct spots (up to three coexistent) on KIC 5110407 (T_{eff} = 5211 K, log g = 3.838), with spot lifetimes of six to 40 rotation periods (3.458 days), and evidence for differential rotation ($\Delta\Omega = 1.674^{\circ}$/day).

We acknowledge support from the NASA Harriett G. Jenkins Pre-Doctoral Fellowship Program.

104.02 – **Asteroseismology Of The Kepler DBV - It's a Hot One!**

Agnes Kim[1], R. Ostensen[2]

[1]*Georgia College & State University,* [2]*Instituut voor Sterrenkunde, K.U. Leuven, Belgium.*

10:10 AM - 10:20 AM

We present an asteroseismic analysis of the DBV recently found in the field of view of the Kepler satellite. We analyze the 5-mode pulsation spectrum that was produced

based on one month of high cadence Kepler data. The pulsational characteristics of the star and the asteroseismic analysis strongly suggest that the star is hotter (29200 K) than the 24900 K suggested by model fits to the low S/N survey spectrum of the object. This result has profound and exciting implications for tests of the Standard Model of particle physics. Hot DBVs are expected to lose over half of their energy through the emission of plasmon neutrinos. Continuous monitoring of the star with the Kepler satellite over the course of 3 to 5 years is not only very likely to yield more modes to help constrain the asteroseismic fits, but also allow us to obtain a rate of change of any stable mode and therefore measure the emission of plasmon neutrinos.

104.03D – **White-Light Continuum Emission in M Dwarf Flares**

Adam Kowalski[1], S. L. Hawley[1]

[1]*University of Washington.*
10:20 AM - 10:40 AM

A primary mode of radiative energy release in stellar flares is the optical and near-ultraviolet (NUV) continuum. However, radiative-hydrodynamic models of stellar flares using a solar flare paradigm and the sparse observations of solar and stellar flare continua are all seemingly in disagreement over the type(s) of emission that contribute to the optical/NUV continuum during flares. We have completed a long-term flare monitoring campaign using simultaneous low-resolution (3400-9200A) spectroscopic and broadband photometric observations to fully characterize the optical/NUV white light continuum emission on short timescales. To date, our most significant results come from observations during the decay phase of a megaflare on the dM4.5e star YZ CMi, where we have detected multiple continuum components that contribute to the white light near the Balmer jump (3646A). We present a time-resolved spectral analysis of the continuum components and emission lines for this flare and for several other large and small flares obtained during our spectroscopic monitoring campaign. We compare these data to phenomenological flare models with the RH code and to preliminary results from the next-generation of radiative-hydrodynamic 1D flare models with the RADYN code.

Funding for this project has been provided by NSF AST 0807205. Observations were obtained with the ARC 3.5m, the NMSU 1m, and the ARCSAT 0.5m at the Apache Point Observatory.

104.04D – **Exploring the Long-term and Extreme Variability of Stars**

Sumin Tang[1]

[1]*Harvard University.*
10:40 AM - 11:00 AM

Stellar variations over decades are poorly explored. With the unique 100 yr coverage of DASCH (Digital Acess to a Sky Century@Harvard), for the first time, we are able to study the variable sky over long timescales in a systematic way. We have discovered exciting new types of long-term variables, which do not match any of the common classes. The most interesting one to date is a peculiar 10-yr nova powered by quasi-steady Hydrogen burning triggered by accretion disk instability. There is no significant mass loss, and it could be a promising channel for Type Ia Supernovae (SNe). It provides new insights into our understanding of SNe Ia progenitors, as well as binary evolution and accretion physics, thus allowing optimization for the use of SNe Ia for cosmology. We have found peculiar long-term K giant variables with 1-2 mag slow variations over decades. Most of them show strong Ca H&K emission, and 5 of them are covered by Kepler and show (in 4 stars) star spots and flaring activities. This suggests that the mysterious long-term variations may be related to strong star spots and magnetic activities which may be a new mechanism for dust formation or ejection. Other discoveries include a 5-yr dust accretion event in KU Cyg and a group of large amplitude Be variables which might be Be X-ray binaries. Using the limited DASCH scanning coverage (thus far) and sample of different classes found, we estimate the likely event rate or populations for each class.

104.05 – **Optical Through Mid-infrared Period-luminosity Relations Of Rr Lyrae Stars**

Christopher R. Klein[1], J. W. Richards[2], N. R. Butler[3], J. S. Bloom[1]

[1]*UC Berkeley Astronomy Department,* [2]*UC Berkeley Statistics Department,*

[3]*Arizona State University School Of Earth and Space Exploration.*
11:00 AM - 11:10 AM

For more than a century RR Lyrae pulsating variable stars have been reliable distance indicators. Originally termed cluster variables, as our technological capabilities to observe their light curves with greater precision, improved temporal resolution, and expanded wavelength coverage advanced, these horizontal branch pulsators have continued to provide increasingly accurate distance measurements. Here we present very well observed local RR Lyrae variables with photometric data at wavebands ranging from 0.36 to 12 μm (optical: UBVR, near-infrared: JHK, mid-infrared: WISE W1, W2, W3). In total our data spans 103 RR Lyrae variables; 12 of which have complete U-W3 coverage, 10 have U-K, and 14 have J-W3. We calibrate the RR Lyrae period-luminosity relations simultaneously in all 10 wavebands with a Bayesian linear model fit.

104.06D – **Phurbas: An Adaptive, Lagrangian, Meshless, Parallel, Magnetohydrodynamics Code**

Colin McNally[1], J. L. Maron[2], M. Mac Low[1]

[1]*AMNH / Columbia U.,* [2]*AMNH.*
11:10 AM - 11:30 AM

We present an algorithm for simulating the equations of ideal magnetohydrodynamics and other systems of differential equations on an unstructured set of points represented by sample particles. Local, third-order, least-squares, polynomial fits are calculated from the field values of neighboring particles to derive field values and spatial derivatives at the particle position. Field values and particle positions are advanced in time with a second order predictor-corrector scheme. The particles move with the fluid, so the time step is not limited by the Eulerian Courant-Friedrichs-Lewy condition. Full spatial adaptivity is required for stability, and gives the algorithm substantial flexibility and power. A target resolution is specified for each point in space, with particles being added and deleted as needed to meet this target. Particle addition and deletion is based on a local void and clump detection algorithm. Novel stabilization operators are used to filter high-frequency modes and provide diffusion in shocks. Globally conserved quantities are maintained constant by differentially adjusting regions of large change. We describe the parallel implmentation and show a suite of tests, including linear amplitude waves, shock tubes, and magnetrotational instability. We discuss the novel ways magnetic divergence errors can be controlled in a point collocation method and the control of such errors is demonstrated. We also describe a rigorous methodology for showing

the correctness of numerical solutions to a well posed Kelvin-Helmholtz (KH) problem including demonstrations in several codes. This methodology clarifies the ongoing controversy about the differences seen in KH instability grid codes, moving mesh codes, and in particular highlights the consequences of the zeroth order inconsistency in Smoothed Particle Hydrodynamics.

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105 – Enhancing Astronomy Research in Hawai'i: Balancing Science and Culture

Special Session – Room 12B – Monday, January 9, 2012, 10:00 AM - 11:30 AM

AAS's Position Statement "On Women, Under-Represented Groups and the Baltimore Charter," states that the AAS is committed to addressing issues of attitude and procedure that negatively impact any group. This position has direct implications to the continued use of indigenous people's sacred sites as crucial resources to the astronomy community. The ongoing evolution of astronomy in the cultural context of the Hawaiian islands provides an opportunity to reformulate the conflict between science and culture, into a relationship that is mutually beneficial and respectful. The restoration of balance in Hawai'i places astronomy in a position of being able to do better science, while providing guidance for more effective observatory management in other locations. This 90 minute session will provide AAS members with an update of promising practices for conducting astronomy in culturally diverse regions. Experts representing the perspectives of Hawaiian scientific and cultural entities will describe the current and future potential of astronomy science and astronomy education, cultural practices, and workforce development activities in Hawaii.

Using a non-traditional format, this session engages participants in a unique combination of presentations by invited speakers. As such, attendees need to be aware that the "talks" for this session will not follow the standard time allocations, with some presentations being allocated more time while others taking less. Participants are encouraged to stay the entire session rather than "come and go." Immediately following the session, presenters and participants will continue the discussion in a nearby location announced during the final session.

105.01 – **New Opportunities for Astronomy in Hawaii**

Guenther Hasinger[1]

[1]*University of Hawaii.*
10:00 AM - 10:10 AM

As one of the premier astronomy sites in the world, Hawai'i is well positioned to assume a leadership role in the development of the next generation of the world's most powerful ground-based telescopes: the Thirty Meter Telescope (TMT), the Advanced Technology Solar Telescope (ATST), and Pan-STARRS, all slated for the Hawaiian islands. The development of these new facilities represents great scientific potential for the astronomy research community.

Pan-STARRS, an innovative wide-field imaging facility developed at IfA, has been operational via its first telescope, PS1, since 2010. With the largest digital camera ever built - 1.4 Gigapixels - and an unprecedented field of 7 deg^2, PS1 generates a time-lapse movie of the Northern sky in 5 pass-bands. PS1 has already discovered a number of potentially hazardous asteroids, comets, and a new class of very luminous supernova explosions. The second telescope, PS-2, is under construction on Haleakala, with an ultimate aim a four-telescope system in one enclosure on Mauna Kea.

Haleakala--the House of the Sun--is the best place on Earth for solar astronomy and has therefore been chosen by NSF as the site of the world's largest solar telescope, the ATST. ATST will employ a 4m primary mirror with a unique off-axis design optimized for high-contrast solar imaging and spectropolarimetry. Construction, which is already funded, is expected to start soon with two of the first-light instruments being developed in Hawaii.

The TMT, ready for construction on Mauna Kea, will be among the world's most advanced ground-based observatories, operating in wavelengths ranging from the ultraviolet to mid-infrared, integrating the most modern innovations in precision control, segmented mirror design, and adaptive optics. It will address bold scientific questions like the search for habitable extrasolar planets, the First Light in the Universe, the earliest Black Holes and the nature of space itself.

105.02 – **The Future of Astronomy Research at the Maunakea Observatories**

Scott Fisher[1], R. Tseng[2]

[1]*Gemini Observatory,* [2]*University of Hawai'i - Hilo.*

10:10 AM - 10:20 AM

Above the clouds on the summits of the Big Island of Hawai'i, the Maunakea Observatories (MKO) stand as the world's largest astronomical observatory, with telescopes operated by astronomers from eleven countries. This presentation will discuss the factors that make Maunakea a unique astronomical observing site, including characteristics related to seeing at the MKO, and the observatory's political and physical infrastructure. A brief inventory of current observing facilities will be given, with insights into each telescope's ten-year horizon.

105.03 – **Challenges and Opportunities in Developing the Hawaiian Scientific and Technical Workforce**

James R. Kennedy[1]

[1]*County of Hawai'i Workforce Investment Board.*

10:20 AM - 10:30 AM

In searching for dark skies, persistently clear weather, and minimal atmospheric interference, astronomical observing sites are generally located in remote, mountainous locations, and usually far from large communities. Such locations often have weak economies, and shallow workforce pools in the technical and administrative areas generally needed by the observatories. This leads to a problem, and an opportunity, for both the observatories and their local communities. Importing employees from far away locations is costly, leads to high turnover, and deprives the community of economic benefits and the sense of fealty with the observatories that would naturally result if local people occupied these comparatively good paying jobs. While by no means unique, the observatories on Mauna Kea Hawai'i are a clear example of this dual dilemma.

This presentation will report findings from a model workforce needs assessment survey of all the Mauna Kea observatories, which has establish likely annual staffing requirements in several categories of technological and administrative support, including the educational entrance requirements. Results indicated that through 2023, 80% of observatory job openings on Hawai'i Island will be in technology and administration. Furthermore, the vast majority of these jobs will require only a two-year or four-year college degree in a relevant field as an entrance requirement. Efforts to realign the existing resources to better meet these common needs will be discussed, including the highly successful partnership between County of Hawai'i Workforce Development Board, the Mauna Kea observatories, the local K-12 systems, Hawai'i Community College, the University of Hawai'i Hilo, and a number of informal education and workplace experience programs. This collaboration has resulted in no fewer than three, interlocked, community programs have stepped up to meet this challenge to the benefit of both the local community and the observatories.

105.04 – **Lenses for Seeing Astronomy in Hawaii**

Lehua M. Veincent[1]

[1]*Department of Education, State of Hawai'i.*

10:30 AM - 10:40 AM

It is well know that there has been a history of societal and cultural conflict surrounding the development of Western astronomy science in Hawai'i. To the outside observer, it may seem that the conflict is a residual effect from the manner in which the observatories were built, or that Native Hawaiians simply do not want outsiders encroaching on sacred mountains. While there may be some in the Islands who strongly argue against the observatories for these reasons, there are also individuals that support the idea of such needed research in this progressive time of technology. More importantly, these explanations are overly simplistic. What cultural experts, practitioners and liaisons now recognize is that much of the unexpected difficulties encountered in developing the Hawaiian workforce, science, technologies and sympathies to support the observatories, lie in a failure to understand the Native Hawaiian ontology related to themselves and their place in the world. One very simple way to characterize a Native Hawaiian worldview is that astronomy is not an isolated subject of study; rather, astronomy serves as a deeply interconnected human interface between the ocean, the land, language, genealogy, and a sense of place. In this paper Ke Kumu Lehua Veincent will describe the Hawaiian worldview, and shed light on the problem areas where this worldview, and the strictly academic view of astronomy come into conflict. Cultural intelligence and ancestral knowledge is also brought forth that suggests a much needed pathway in which these two viewpoints can engage and coexist with *pono,* or with balance without compromising what was, what is, and what is yet to come striving for continuous improvement, in science and for the people of Hawai'i.

105.05 – **Evolving Perspectives on Astronomy Education and Public Outreach in Hawai'i**

Ka'iu Kimura[1], T. Slater[2], J. Hamilton[3], V. Takata[4]

[1]*'Imiloa Astronomy Center,* [2]*Center for Astronomy & Physics Education Research,* [3]*University of Hawai'i,* [4]*Department of Education, State of Hawai'i.*

10:40 AM - 10:50 AM

For the last several decades, well meaning astronomers and educators have worked diligently to provide astronomy education experiences to Native Hawaiians and visitors across all the islands. Much of the early education and public outreach (EPO) work was based on a philosophical perspective based on the notion of, "if we just make them aware of how wonderful astronomy is, then everyone will naturally support the development of astronomy in the islands." In support of this goal, numerous teacher workshops were delivered and the first generation of the Maunakea Observatories Visitors' Center was developed and funded. These projects were most frequently developed using Mainland thinking, in a Mainland style, with a Mainland agenda. Consequently, these efforts often failed to create even moderate impacts, whether in educational settings, or in terms of public outreach. In recent years, our understanding of effective EPO has evolved. This evolution has led to a shift in the locus of control, from the Mainland to the Islands; and in content, from "astronomy only" to "astronomy as part of the whole." We have come to understand that successfully transformative EPO requires intertwining astronomy with teaching about culture, language and context. In response, the 'Imiloa Astronomy Center was expanded to convolve historical and modern astronomy with Hawaiian culture and language. Moreover, the most successful astronomy EPO programs in the islands have been redesigned to reflect meaningful collaborations of schools, businesses, and the larger community that situate astronomy as part of a larger educational work of honoring the traditions of the past while simultaneously transforming the future. This evolution in thinking may serve as a model for the astronomy community's interaction with other regional communities.

105.06 – **Upgrading Our EPO Through Focused Astronomy Education Research**

Stephanie J. Slater[1], A. Dye[2]

[1]*University of Wyoming,* [2]*'Imiloa Astronomy Center.*

10:50 AM - 11:00 AM

Not so long ago, astronomers visiting schools in Hawaii tried to build awareness among school children and teachers about how stars move across the sky, the nature of planets orbiting our sun, and the physical processes governing stars and galaxies. While these efforts were undertaken with all good intentions, they were often based on our collective understanding of how Mainland children come to know astronomy topics, and with a Western worldview. Research observations of Hawaiian elementary school children indicate that Hawaiian children understand far more about the skies than could have been predicted from the behavior of Mainland children, or from the body of literature on children's understanding of astronomy. Analysis of elementary students' responses to a *kumu's,* or teacher's questions relating to the celestial sphere indicate that these students posses a deep knowledge of the night sky and celestial motions. This knowledge base is fluent across two cultural systems of constellations, and is predictive. In an era of curriculum development based upon learning progressions, it appears that Native Hawaiian students possess unexpected knowledge that is well poised to interfere with conventional educational and public outreach approaches if not taken into account. Further, these findings suggest that further inquiry must be made into the astronomical thinking of minority populations prior to the unilateral implementation of national science education standards.

105.07 – **Astronomy in Hawai'i is Where the Ocean Meets the Mountain**

Kalepa Babayan[1]

[1]*'Imiloa Astronomy Center.*

11:00 AM - 11:10 AM

For generations the starry heavens have been a constant companion to oceanic wayfinders as they navigated from island to island. As mariner explorers sailed in search of new landfalls the stars served as signposts along oceanic seaways, recording the direction to new discoveries and return pathways to the distant islands they had sailed from. Given this historical background, and a Hawaiian worldview that sees astronomy as interconnected with the ocean and the land, educators at ‘Imiloa Astronomy Center have created a series of educational experiences that allow learners to integrate indigenous and western paradigms. Culture and Science Integration Hawai’i (CSI Hawai’i), is an example of a uniquely Hawaiian approach to learning, that focuses on a specific cultural practice and explores common intersections with science. This paper describes CSI Hawai’i and other culturally relevant examples of education and public outreach that are successfully engaging learners in astronomy, in addition to language, culture, and sustainable environmental practices. Presented by master navigator Kalepa Chad Baybayan, this session will include demonstrations and video footage of how navigators use derive clues about position, direction, and distance come from the stars, sun, and moon; from currents, ocean swells, and localized wave characteristics.

106 – The LITTLE THINGS Survey

Special Session – Room 16B – Monday, January 9, 2012, 10:00 AM - 11:30 AM

Dwarf irregular galaxies are the closest analogs in the nearby universe to the low mass dark matter haloes that formed after the Big Bang, and, in the LambdaCDM model, it is in these entities that the first stars formed. Yet, we do not understand the processes that lead to star formation on galactic scales even in nearby dwarfs, the simplest, most pristine local environments. To address the question of what drives star formation in dwarf galaxies, we have assembled a complete dataset on a large sample of relatively normal, nearby gas-rich dwarf galaxies, tracing their stellar populations, gas content, dynamics, and star formation indicators. We are using these data to test and modify star formation models. This project is called LITTLE THINGS (http://www.lowell.edu/users/dah/littlethings/index.html), and it brings together deep, high spatial and high spectral resolution HI-line maps with optical, UV, and IR data of 41 dIm galaxies covering nearly the full range of galactic parameters seen in dwarf galaxies. In this Session we describe the LITTLE THINGS HI data, which are being made available to the public in January 2012, and present some first scientific results. We also present results from the complementary program VLA-ANGST and from the theoretical perspective.
We gratefully acknowledge Large Proposal status at the VLA and funding from the National Science Foundation with grants to DAH (AST-0707563), BGE (AST-0707426), CES (AST-0707468), and LMY (AST-0707835).

106.01 – **The LITTLE THINGS Survey**

Deidre Ann Hunter[1], LITTLE THINGS Team

[1]*Lowell Obs..*

10:00 AM - 10:06 AM

We have assembled a multi-wavelength dataset on 41 relatively normal, nearby (<10 Mpc) gas-rich dwarf irregular galaxies for the purpose of determining the drivers for star formation in these systems. This project is called LITTLE THINGS (Local Irregulars That Trace Luminosity Extremes, The HI Nearby Galaxy Survey). Our data include GALEX UV images, ground-based UBV and Halpha images, some ground-based JHK images, Spitzer archival mid-IR images, and HI-line maps. The HI maps, obtained with the VLA, go deep (12/6/2 hrs in B/C/D arrays) and are characterized by high spectral resolution (</=2.6 km/s) and high angular resolution (typically 6", which is 110 pc at the average distance of our sample). Our datasets trace the stellar populations, gas content and structure, dynamics, and star formation indicators in the galaxies, and are being used to answer the following questions: What regulates star formation in small, gas-rich galaxies? What is the relative importance of sequential triggering for star formation in dwarf galaxies? What is the relative importance of triggering of star formation by random turbulent compression in dwarf galaxies? What happens to the star formation process in the outer parts of disks? What happens to the star formation process at breaks in the exponential light profiles? And, what happens in Blue Compact Dwarf galaxies?

The LITTLE THINGS team is grateful to the National Science Foundation for funding through grants AST-0707563, AST-0707426, AST-0707468, and AST-0707835 to DAH, BGE, CES, and LMY.

106.02 – **Star Formation Laws in LITTLE THINGS Dwarfs: The Case of DDO133 and DDO168**

Dana Ficut-Vicas[1]

[1]*University of Hertfordshire, United Kingdom.*

10:08 AM - 10:18 AM

We present the results of our pilot study of the star formation (SF) characteristics of two LITTLE THINGS dwarfs: DDO133 and DDO168. For each galaxy, we combine HI spectral line VLA radio interferometric observations in B-, C-, and D-configurations into one data set of high resolution and quality which allows an in depth investigation of their HI distribution and kinematics. We focus our interest on their SF characteristics extending current investigations of the Schmidt-Kennicutt law to the low luminosity, low metallicity regime. To do this, we combine our HI maps with GALEX ultraviolet, Spitzer infrared and, where available, CO data in order to measure the surface densities of HI, H2 and the SFR surface density for the galaxies in our sample. We find a general lack of Spitzer 24 micron emission which fits in with our result that internal extinction is less than 0.1 mag, indicating a dust-poor ISM. Our results overlap with those published on a number of THINGS dwarfs and confirm the finding that the SF characteristics of dwarfs resemble those in the outskirts of spirals. The study applied to DDO133 and DDO168 is being extended to a larger LITTLE THINGS subsample, which will be the subject of a future paper.

106.03 – **High-resolution Rotation Curves And Mass Models Of Little Things**

Se-Heon Oh[1]

[1]*University of Western Australia, Australia.*

10:20 AM - 10:30 AM

We present high resolution rotation curves and mass models of 34 nearby dwarf galaxies culled from LITTLE THINGS. The high-resolution HI observations (~6" angular; < 2.6 km/s velocity resolution) of LITTLE THINGS enable us to derive reliable rotation curves of the galaxies in a homogeneous and consistent manner. The rotation curves are combined with Spitzer archival 3.6 micron and ancillary optical UBV images to construct mass models. The high quality multi-wavelength dataset significantly reduces observational uncertainties and thus allows us to examine in detail the dark matter distribution in the galaxies. We compare the derived dark matter distributions of the sample galaxies with those of dwarf galaxies from The HI Nearby Galaxy Survey (THINGS). From this, we find that they are consistent with each other in terms of (1) the rotation curve shape, showing a linear increase in the inner regions, and (2) a shallow slope of the mass density in the inner parts, resulting in dark matter halos characterised by a core. This is in contrast with classical dark-matter-only cosmological simulations, which predict a steep rotation curve in the central region and steep inner slope of the dark matter density profiles. Instead, our results are more in line with shallower slopes found in LambdaCDM simulations of dwarf galaxies in which the effect of baryonic feedback processes is included.

106.04 – **NGC 1569 stellar and gas kinematics**

Megan C. Johnson[1]

[1]*NRAO.*

10:32 AM - 10:42 AM

The evolution and formation of dwarf galaxies has great importance to our knowledge of cosmological history from the Big Bang through the present day structure we observe in our local universe. Dwarf galaxies are believed to be the "building blocks" of larger galaxies, which implies that interactions and mergers of these small systems must have occurred frequently in the early universe. There is a population of starburst dwarf irregular (dIm) galaxies that seem to have characteristics indicative of interactions or mergers. One of these dIm galaxies is the nearby post-starburst NGC 1569. We explore the stellar and gas kinematics of NGC 1569 as well as examine a deep HI map made using the Robert C. Byrd Green Bank Telescope (GBT). From these observations, we analyze the evolution of NGC 1569 by understanding the three-dimensional shape of this dIm system. The structure of dIm galaxies is an important fundamental, physical property necessary to understand the evolution and formation of these common systems.

106.05 – **Stellar Surface Brightness Profiles of Dwarf Galaxies**

Kimberly A. Herrmann[1], LITTLE THINGS team

[1]*Lowell Observatory.*

10:44 AM - 10:54 AM

Radial stellar surface brightness 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 surface brightness profile breaks are also found in dwarf disk galaxies, but with an additional category: (FI) flat-inside: the light is roughly constant or increasing and then falls off beyond a break. We have been re-examining the multi-wavelength stellar disk profiles of 141 dwarf galaxies, primarily from Hunter & Elmegreen (2006, 2004). Each dwarf has

data in up to 11 wavelength bands: FUV and NUV from GALEX, UBVJHK and H-alpha from ground-based observations, and 3.6 and 4.5 microns from Spitzer. In this talk, I will highlight results from a semi-automatic fitting of this data set, including: (1) statistics of break locations and other properties as a function of wavelength and profile type, (2) color trends and radial mass distribution as a function of profile type, and (3) the relationship of the break radius to the kinematics and density profiles of atomic hydrogen gas in the 41 dwarfs of the LITTLE THINGS subsample.

We gratefully acknowledge funding for this research from the National Science Foundation (AST-0707563).

106.06 – **The Growth of the Stellar Disks of Dwarf Irregular Galaxies**

Hongxin Zhang[1]

[1]*Lowell Observatory.*
10:56 AM - 11:06 AM

The picture of how stellar disks form and grow in dwarf irregular galaxies is far from clear. We initiated a study of the relationship between the star-forming disk, the "backbone" old stellar disk, and the HI gas disk for the dwarf irregular galaxies included in the LITTLE THINGS survey. The data that we used include images from GALEX FUV/NUV, ground-based UBV, narrow-band H-alpha, near-IR J, and Spitzer 3.6 micron, as well as VLA HI surface density maps. In this talk, first, I will present the radial variations of the azimuthal averages of recent star formation and stellar mass surface density for 34 of the LITTLE THINGS galaxies, and then explore: 1) the radial evolution of the star-forming disk, and 2) the relationship between the surface density of star formation and stellar mass. Secondly, for a subsample of 10 face-on LITTLE THINGS galaxies, I will present the power spectra for the azimuthal scans of the FUV, B, V, and HI maps. I will discuss to what degree, and on what scales, recent star formation, the old stellar disk, and gas distribution correspond with each other as a function of radius.

106.07 – **VLA-ANGST: The Influence of Stellar Populations on the HI Shapes and Gas Dynamics in Galaxies**

Juergen Ott[1], A. Stilp[2], S. Warren[3], E. Skillman[3], J. Dalcanton[2], F. Walter[4], E. de Blok[5]

[1]*NRAO,* [2]*University of Washington,* [3]*University of Minnesota,* [4]*Max-Planck-Institut fuer Astronomie, Germany,* [5]*University of Cape Town, South Africa.*
11:08 AM - 11:18 AM

Star formation has a profound impact in the interstellar medium, in the form of radiation and mechanical energy mainly originating from massive stars. In turn, the ISM properties determine where and how strong star formation takes place. This gas-star formation interplay is thus an important driver that regulates galaxy-wide star formation and therefore the evolution of galaxies. The "ACS Nearby Galaxy Survey Treasury" (ANGST) survey aims to study the resolved, stellar population of a volume limited sample of nearby galaxies with the resolving power and sensitivity of the HST. Major data products include spatially resolved maps of star formation as a function of look-back time (typically up to 500 Myr). The HI counterparts are studied with the large VLA follow up survey VLA-ANGST. We present morphologic and kinematic studies of the HI as a function of the underlying stellar population. This includes the gas velocity dispersion that may be driven by the mechanical energy deposited by the massive stars, as well as the larger scale morphologies in the form of bubbles, shells and rings. We find that stars at the location of HI features do fulfill the energy requirements needed to reshape the ISM by more than an order of magnitude over the timespan set by their individual dynamical ages. On smaller scales of individual stars, the direct impact on the gas properties is less obvious, suggesting that the spatial distribution of velocity dispersions is the combined result of star formation over hundreds of Myrs.

106.08 – **How Outflows Turn Cusps into Cores, or How Cold Dark Matter is the Worst Model of Galaxy Formation, Except for all the Others**

Fabio Governato[1]

[1]*University of Washington.*
11:20 AM - 11:30 AM

I will show how rapid gas outflows generated by supernova feedback turn dark matter cusps into cores, solving the long standing controversy between CDM simulations, that predicts cuspy DM profiles and observational evidence in dwarf galaxies, showing strong evidence for DM cores. I will use results from cosmological hydro simulations in a CDM cosmology to make predictions on the central slope of the DM distribution in galaxies over a wide range of stellar masses. I will compare these predictions with results form the THINGS and LITTLE THINGS surveys.

(this research is funded by NASA and the NSF)

107 – Evolution of Galaxies IX

Oral Session – Room 19A – Monday, January 9, 2012, 10:00 AM - 11:30 AM

107.01 – **Impact Of Stellar And Non-stellar Feedback On Intermediate-sized Galaxies In Amr Cosmological Simulations**

Taysun Kimm[1], J. Devriendt[1], A. Slyz[1], Y. Dubois[1]

[1]*Oxford University, United Kingdom.*
10:00 AM - 10:10 AM

We study the role of stellar and active galactic nuclei feedback on intermediate-sized galaxies using Adaptive Mesh Refinement hydrodynamic simulations. It is well known that Milky Way-like galaxies show a deficit of baryons compared to the universal baryonic fraction. This is called the “missing baryon problem”. Supernova feedback is often invoked as a solution to this discrepancy, but recent studies have suggested that different modelling strategies of the feedback can potentially impact results. Moreover, although feedback from active galactic nuclei can suppress star formation in massive clusters, its impact on smaller galaxies is still unclear. In an attempt to better understand the effect of different feedback mechanisms, we have performed high-resolution (10pc) zoom cosmological simulations with various physical ingredients. Based on these simulations, we will discuss the influence of stellar (energetic stellar explosions) and non-stellar (active galactic nuclei) energy sources on galaxy growth.

107.02D – **The Formation And Evolution Of Massive Galaxies And Their Supermassive Black Holes Over The Past 12 Billion Years**

Asa Bluck[1], C. J. Conselice[2], GNS Group

[1]*Gemini Observatory,* [2]*University of Nottingham, United Kingdom.*
10:10 AM - 10:30 AM

We present results from the recently completed GOODS NICMOS Survey, which utilizes 180 orbits of the HST with NIC-3 H-band imaging of >8000 galaxies in the GOODS fields. Moreover, we construct a unique sample of 80 extremely massive galaxies (with log(M*) > 11) at high redshifts (z = 1.7 - 3) and examine their merger properties through morphological and close pair methods. This represents the largest and most thorough merger history examination to date for massive galaxies at high redshifts. We conclude that these galaxies will experience on average 4 - 5 mergers with companion galaxies greater than log(M*) = 9, leading to a stellar mass increase of a factor of two from z = 3 to the present. We present arguments that this merging can explain most of the observed size evolution of up to a factor of five in effective radii over the same epoch of cosmic history. We also examine the AGN sub-sample of these galaxies, concluding that at least one third of all massive galaxies will go through a Seyfert luminosity (or brighter) AGN phase leading to an average massive galaxy releasing through its AGN at least 35 times its binding energy in radiation throughout its lifetime. We observe no strong evolution in the local black hole mass - galaxy stellar mass relation, suggesting that supermassive black holes and their hosts grow principally together over the history of the Universe. We also note that it is massive galaxy Seyferts which dominate the X-ray luminosity function at all redshifts, up to z = 3. The profound implications of these processes will be discussed in relation to massive galaxy formation and evolution. This work was funded by the STFC, the Leverhulme Trust, and NASA/STSci grant HST-GO11082.

107.03 – **A Systematic Approach to the Discoveries of Dual Supermassive Black Holes**

Julia M. Comerford[1]

[1]*The University of Texas.*
10:30 AM - 10:40 AM

Dual supermassive black holes (SMBHs) with kpc-scale separations are an expected consequence of galaxy mergers, yet surprisingly few dual SMBHs have been observed to date. Dual SMBHs are observable when they power dual active galactic nuclei (AGN). Galaxies with double-peaked AGN emission lines in the Sloan Digital Sky Survey are plausible dual AGN candidates, but their double-peaked profiles could also be the result of small-scale gas kinematics or AGN-driven outflows and jets. To help distinguish between these scenarios, we obtain spatial profiles of the AGN emission via follow-up longslit spectroscopy. Our results both narrow the list of possible physical mechanisms producing the double AGN components, and suggest several observational criteria for selecting the most promising dual AGN candidates. Our follow-up Chandra observations of these promising candidates show which are bona fide dual AGN. This systematic approach to identifying dual AGN will enable, for the first time, the assembly of a large observational catalog of dual SMBHs, which will provide observational constraints on the galaxy merger rate, SMBH growth, and SMBH coalescence.

This work is supported by NSF grant AST-1102525.

107.04 – **Evidence for Gas Accretion into Distant Massive Galaxies from the GOODS NICMOS Survey**

Christopher Conselice[1], A. Mortlock[1], A. F. L. Bluck[2]

[1]*Univ. of Nottingham, United Kingdom,* [2]*Gemini Observatory.*
10:40 AM - 10:50 AM

We discuss a full analysis of the modes of galaxy formation for massive galaxies with log M > 11 at z < 3 based on data from the Hubble GOODS NICMOS Survey. I will discuss the role of major mergers, star formation, and for the first time, minor mergers, in the formation of massive galaxies from z=3 until today. This is possible due to using new near-infrared Hubble Space Telescope imaging from NICMOS focused on massive galaxies in the distant universe. I will further show that modes besides the above are needed to form galaxies and will argue that gas accretion from the intergalactic medium is an important method for adding mass to these massive galaxies, and potentially a major new part of the galaxy formation process.

107.05 – **Supermassive Black Hole Mass and Spiral Galaxy Pitch Angle at Intermediate to High Redshift**

John A. Hughes[1], R. S. Barrows[1], J. C. Berrier[2], B. L. Davis[1], D. Kennefick[2], J. D. Kennefick[2], C. H. S. Lacy[2], M. S. Seigar[3], D. W. Shields[2], K. A. Zoldak[1]

[1]*University of Arkansas, Arkansas Center for Space and Planetary Sciences,* [2]*University of Arkansas, Department of Physics, Arkansas Center for Space and Planetary Sciences,* [3]*University of Arkansas at Little Rock, Department of Physics, Arkansas Center for Space and Planetary Sciences.*

10:50 AM - 11:00 AM

A possible correlation between spiral galaxy pitch angle (P) and the mass of the central supermassive black hole (SMBH) of the galaxy (M) was reported (Seigar et al. 2008) from a sample of 27 nearby galaxies. Here we investigate the extension of this result to intermediate and high redshifts. We have selected AGN showing spiral structure in their host galaxies from the GOODS fields and from a sample of AGN with reverberation mapping SMBH mass estimates. After careful measure of the pitch angle of these galaxies, we compare the mass found from the M-P relation to that reported from reverberation mapping or estimated from their MgII profiles. By extending the sample to higher redshift, we demonstrate how the M-P relationship can be used to estimate the mass of SMBHs in the center of galaxies with imaging data alone, a useful tool in the study of galaxy evolution.

107.06D – **Hα Star Formation Rates of IRAC-selected Clusters in the Early Universe**

Gregory Zeimann[1], S. A. Stanford[1], R. H. Becker[1], M. Brodwin[2], A. H. Gonzalez[3], D. Stern[4], A. Dey[5], P. Eisenhardt[4]

[1]*UC Davis,* [2]*University of Missouri,* [3]*University of Florida,* [4]*JPL/Caltech,* [5]*NOAO.*

11:00 AM - 11:20 AM

Galaxy clusters in the local universe consist of mostly massive, red galaxies with little or no recent star formation. To understand the stellar mass build-up of such massive galaxies requires a statistical sample of the progenitors of these galaxy clusters covering a redshift range when the star formation rates were near their peak. Using the Wide Field Camera 3 (WFC3) on the Hubble Space Telescope, we obtained low-resolution near-IR grism spectroscopy (G141, 1.10 - 1.65 μm) to identify Hα emitters in a sample of 17 IRAC-selected, $1 \leq z \leq 1.5$ galaxy clusters. We used Hα emission as our star formation indicator and were able to study the star formation properties of cluster galaxies in the core. The accompaniment of high-resolution WFC3 images (F160W) provided morphologies of many of the star forming galaxies and showed that a large fraction, ~ 60%, of these galaxies are spiral in type. Also, we measured an increasing star formation rate density toward the cluster center for higher redshift clusters, $z \geq 1.37$, possibly indicating a reversal of the relation at lower redshift. This is consistent with our MIPS star formation measurements of the same cluster sample.

107.07 – **Ground-based Submm/mm Follow-up Observations For Wise Selected Hyper-luminous Galaxies**

Jingwen Wu[1], C. Tsai[2], D. Benford[3], C. Bridge[4], P. Eisenhardt[1], A. Blain[5], J. Sayers[1], S. Petty[6], WISE team

[1]*Jet Propulsion Laboratory,* [2]*IPAC,* [3]*GSFC,* [4]*Caltech,* [5]*U. Leicester, United Kingdom,* [6]*UCLA.*

11:20 AM - 11:30 AM

One of the major objectives of NASA's Wide-field Infrared Survey Explorer (WISE) mission is to search for the most luminous galaxies in the universe. The most productive method so far to select hyper luminous galaxies from WISE is to select targets that undetectable by WISE at 3.4 and 4.6 microns, while clearly detected at 12 and 22 microns, the so called W12 dropout galaxies. We have used the Caltech Submillimeter Observatory to follow-up these high-z (z=1.6-4.6) galaxies with SHARC-II at 350 to 850 microns, and BOLOCAM at 1.1 mm. Based on Spitzer 3.3 and 4.7 microns follow-ups, WISE W3, W4, and CSO observations, we constructed the SEDs and estimate the infrared luminosity and dust temperature for these W12 dropout galaxies. The inferred infrared luminosities are at least 10^13 to 10^14 solar luminosities, making them one of the most luminous population. The typical SEDs of these galaxies are flat from mid-IR to submillimeter, peaking at shorter wavelengths than other infrared luminous galaxies, indicating hotter dust temperature than known populations. Their SEDs can not be well fitted with existing templates, suggesting they may be a distinct new population. They may be extreme cases of Dust-Obsecured Galaxies (DOGs) with very high luminosities and dust temperature, and tracing a short transiting phase with booming luminosity at the peak epoch of AGN/starburst galaxy evolution.

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108 – Exciting Astrophysics: Supernovae, Relativistic Astrophysics and Other Results I

Oral Session – Room 16A – Monday, January 9, 2012, 10:00 AM - 11:30 AM

108.01 – **Self-Calibration Technique for 3-point Intrinsic Alignment Correlations in Weak Lensing Surveys**

Michael A. Troxel[1], M. Ishak[1]

[1]*University of Texas at Dallas.*

10:00 AM - 10:10 AM

The intrinsic alignment (IA) of galaxies has been shown to be a significant barrier to precision cosmic shear measurements. Zhang [P. Zhang, Astrophys. J. 720, 1090 (2010)] proposed a self-calibration technique for the power spectrum to calculate the induced gravitational shear-galaxy intrinsic ellipticity correlation (GI) in weak lensing surveys with photo-z measurements which is expected to reduce the IA contamination by at least a factor of 10 for currently proposed surveys. We confirm this using an independent analysis and propose an expansion to the self-calibration technique for the bispectrum in order to calculate the dominant IA gravitational shear-gravitational shear-intrinsic ellipticity correlation (GGI) contamination. We first establish an estimator to extract the galaxy density-density-intrinsic ellipticity (ggI) correlation from the galaxy ellipticity-density-density measurement for a photo-z galaxy sample. We then develop a relation between the GGI and ggI bispectra, which allows for the estimation and removal of the GGI correlation from the cosmic shear signal. We explore the performance of these two methods, compare to other possible sources of error, and show that the GGI self-calibration technique can potentially reduce the IA contamination by up to a factor of 5-10 for all but a few bin choices, thus reducing the contamination to the percent level. The self-calibration is less accurate for adjacent bins, but still allows for a factor of three reduction in the IA contamination. The self-calibration thus promises to be an efficient technique to isolate both the 2-point and 3-point intrinsic alignment signals from weak lensing measurements.

This work was supported in part by grants from NSF and NASA.

108.02 – **A New Microlensing Event in the Doubly-Imaged Quasar Q0957+561?**

Laura J. Hainline[1], C. W. Morgan[1], C. S. Kochanek[2], H. C. Harris[3], R. Fadely[4], E. E. Falco[5], T. Tilleman[3]

[1]*U. S. Naval Academy,* [2]*Ohio State University,* [3]*U. S. Naval Observatory, Flagstaff Station,* [4]*Haverford College,* [5]*Harvard-Smithsonian Center for Astrophysics.*

10:10 AM - 10:20 AM

We present evidence for ultraviolet/optical microlensing in the gravitationally lensed quasar Q0957+561. We combine new measurements from our optical monitoring campaign at the United States Naval Observatory, Flagstaff with measurements from the literature and find that the time-delay-corrected *r* band flux ratio $m_A - m_B$ has increased by ~0.06 magnitudes over a period of six years beginning in the fall of 2005. We apply our Monte Carlo microlensing analysis procedure to the composite light curves, obtaining a measurement of the optical accretion disk size, $\log (r_S/\mathrm{cm}) = 16.3^{+0.4}_{-0.7}$, that is consistent with the quasar accretion disk size - black hole mass relation.

108.03 – **Pulsar Timing Arrays: No longer a blunt instrument for Gravitational Wave Detection**

Andrea N. Lommen[1]

[1]*Franklin and Marshall College.*

10:20 AM - 10:30 AM

The limits that pulsar timing places on the energy density of gravitational waves in the universe are on the brink of limiting models of galaxy formation and have already placed limits on the tension of cosmic strings. Pulsar timing has traditionally focused on stochastic sources, but most recently I have been investigating the idea of detecting individual gravitational wave bursts wherein there are some interesting advantages. I will demonstrate how the array can be used to reconstruct the waveform and obtain its direction, making it a shrewd gravitational wave detection instrument. With this new strategy comes interesting questions about how best to optimize the array given our current resources.

108.04 – **Searches for Continuous Gravitational Waves from Spinning Neutron**

Stars with the LIGO and Virgo Detectors

Keith Riles[1], LIGO Scientific Collaboration, Virgo Collaboration

[1]*University of Michigan.*
10:30 AM - 10:40 AM

The LIGO Scientific Collaboration and Virgo Collaboration have carried out joint searches in LIGO and Virgo data for periodic continuous gravitational waves. These analyses range from targeted searches for gravitational-wave signals from known pulsars, for which precise ephemerides from radio or X-ray observations are used in matched filters, to all-sky searches for unknown neutron stars, including stars in binary systems. Between these extremes lie directed searches for known stars of unknown spin frequency or for new unknown sources at specific locations, such as near the galactic center or in globular clusters. Recent and ongoing searches of each type will be summarized, along with prospects for future searches using data from the Advanced LIGO and Virgo detectors.

108.05 – **The Galactic Compact-binary Population As Target And Noise Source For Low-frequency Gravitational-wave Astronomy**

Michele Vallisneri[1], S. Nissanke[1], T. A. Prince[2], G. Nelemans[3]

[1]*Jet Propulsion Laboratory,* [2]*California Institute of Technology,* [3]*Radboud University, Netherlands.*
10:40 AM - 10:50 AM

Ultra-compact Galactic binaries, where at least one member is a white dwarf or neutron star, constitute the majority of individually detectable sources for future low-frequency space-based GW observatories such as ESA's NGO; in addition, they may form the dominant unresolvable Galactic foreground at frequencies below a few mHz. So far the majority of studies involving Galactic binaries have been based on theoretical population synthesis, due to the paucity of electromagnetic observations. Recently, significant observational progress has been made in detecting new systems of compact single or double white dwarf binaries. We consider the impact of revised local space density estimates of compact white dwarf binaries on low-frequency GW observations, and discuss the particular case of NGO, a candidate to ESA's Cosmic Vision large-mission program.

108.06 – **The Rate of Core Collapse Supernovae in Galaxy Clusters**

Melissa Graham[1], D. J. Sand[1], C. Bildfell[2], D. Zaritsky[3], C. Pritchet[2], H. Hoekstra[4]

[1]*LCOGT/UCSB,* [2]*University of Victoria, Canada,* [3]*Steward Observatory,* [4]*Leiden Observatory, Netherlands.*
10:50 AM - 11:00 AM

The rate of core collapse supernovae, the deaths of massive stars, measures the amount and distribution of star formation in an environment. This is particularly useful for galaxy clusters, in which most of the stellar mass is in the old stellar populations of red sequence galaxies. Trace amounts of star formation in such systems can be difficult to observe directly (with UV, for example), but are revealed by the explosions of young massive stars. The CFHT Multi-Epoch Nearby Cluster Survey (MENeaCS) monitored 60 low redshift, x-ray luminous galaxy clusters with a monthly cadence for two years. We discovered and spectroscopically confirmed 7 Type II-P supernovae (and 23 Type Ia). This talk will present an analysis of the MENeaCS SN II-P rate in galaxy clusters, the ratio between Ia and II rates, properties of the supernova host galaxies, and the implied cluster star formation rate.

108.07 – **Role of Magnetic Fields in Type Ia Supernovae**

Robert Penney[1], P. Hoeflich[1]

[1]*Florida State University.*
11:00 AM - 11:10 AM

We've developed methods to calculate the transport of gamma rays, X-rays, positrons and low energy photons in the rapidly expanding envelopes of Type Ia Supernovae in a single, consistent, fully three-dimensional simulation. This allows the calculation of the late-time near infrared and lightcurves from the three dimensional geometry of the supernova envelope created by varying models of the initial thermonuclear runaway. It also allows us to use these observations as a unique probe of the magnetic field of the Supernova envelope, by predicting the effect of these fields on the positrons which account for most of the energy transport at late times.

Using these methods, we find that a magnetic field of some 10^6 Gauss is necessary to explain some already existing infrared spectra, and that an observational campaign on existing instruments will allow us to further separate geometrical effects from those of the magnetic field. Of particular interest is that these fields are shown to be strong enough, in some cases, to have a large effect on the physics of the thermonuclear runaway during the initial explosion.

108.08 – **The Type Ia Supernova Rate in z~0.1 Galaxy Clusters From the Multi-Epoch Nearby Cluster Survey (MENeaCS)**

David J. Sand[1], M. Graham[1]

[1]*UC Santa Barbara.*
11:10 AM - 11:20 AM

Here we describe the Multi-Epoch Nearby Cluster Survey measurement of the type Ia supernova (SN Ia) rate in a sample of 57 X-ray selected galaxy clusters at $0.05 < z < 0.15$. Using the CFHT/Megacam imager for SN discovery, along with spectroscopy from the MMT and Gemini, we spectroscopically confirmed twenty-three cluster SN Ia, four of which were intracluster events. After detailed detection efficiency simulations and measurement of the stellar luminosities in our clusters, we calculate a SN Ia rate of 0.041+/-0.018 SNuM within R_{200}, and 0.038+/-0.018 SNuM within our red sequence galaxy population. By combining this SN Ia rate with other cluster SN rates at a variety of redshifts, we constrain the late time delay time distribution of SN Ia to go like $t^{-1.64+/-0.54}$. This power law form is most consistent with the double detonation explosion mechanism for SN Ia, but is also consistent with the double degenerate scenario. Future cluster SN rate measurements at moderate redshift will further constrain the SN Ia progenitor.

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109 – AGN, QSO, Blazars I

Oral Session – Room 17A – Monday, January 9, 2012, 10:00 AM - 11:30 AM

109.01 – **Morphology and Structure of AGN Host Galaxies at z ~ 2**

Dale Kocevski[1], S. Faber[1], K. Nandra[2], J. Trump[1], D. Koo[1], A. Koekemoer[3]

[1]*University of California, Santa Cruz,* [2]*Max Planck Institute for Extraterrestrial Physics, Germany,* [3]*Space Telescope Science Institute.*
10:00 AM - 10:10 AM

Using HST/WFC3 imaging taken as part of the CANDELS survey, we have examined the rest-frame optical morphologies of AGN host galaxies at z~2 to determine the role that major galaxy mergers play in triggering AGN activity at this redshift. Our sample consists of 72 moderate-luminosity ($Lx \sim 10^{42-44}$ erg/s) AGN at $1.5<z<2.5$ selected using the 4 Msec Chandra observations in the Chandra Deep Field South. Employing visual classifications, we have determined that AGN hosts do not exhibit merger or interaction signatures more often than non-active galaxies of similar mass at this redshift. Furthermore, although the AGN appear to favor bulge-dominated and spheroidal hosts compared to our control sample, a majority of the AGN are hosted by disk-like galaxies. Our results suggest that the bulk of the X-ray luminous AGN population at z~2 could not have been triggered by a major merger event in the recent past. Instead it appears that secular processes or possibly cold-flow accretion plays a greater role in triggering AGN activity at z~2 than previously thought.

109.02 – **A Detailed Study of Low Eddington Ratio AGN**

Laura Trouille[1], R. Hickox[2]

[1]*Northwestern University CIERA Postdoctoral Fellow,* [2]*Dartmouth College.*
10:10 AM - 10:20 AM

Understanding low Eddington ratio AGN will help us develop a more complete framework for the different modes of AGN accretion (e.g., 'quenching' vs. 'maintenance'-mode) and their effects on host galaxy evolution. We use the unprecedented sensitivity of the 4Ms CDF-S to conduct a detailed study of the X-ray spectra of low Eddington ratio AGN. Using these extremely deep exposures, we measure individual spectra for the brightest sources, and for the fainter sources we use a stacking analysis of the X-ray spectra to measure the average spectra for different subsets. We will discuss the properties (star-formation rate, bulge mass, radio loudness, clustering, and optical emission line widths) of the subsets we find to have relatively low Eddington ratios (Lbol/LEdd<10−2), and hard and unabsorbed X-ray spectra. These objects may represent a radiatively inefficient accretion mode such as found in the "low-hard" state for black hole X-ray binaries.

109.03D – **Quasar Variability - Selection of and Physics in Quasars**

Kasper B. Schmidt[1], H. Rix[1]

[1]*Max Planck Institute for Astronomy (MPIA), Germany.*
10:20 AM - 10:40 AM

Quasars vary intrinsically by ~10% over timescales of year(s). This variability has the potential of becoming an extremely powerful tool for quasar identification in the near future due to present (the Panoramic Survey Telescope & Rapid Response System 1; Pan-STARRS1) and future (the Large Synoptic Survey Telescope; LSST) wide-area multi-epoch surveys. Describing the variability of more than 9000 quasars from SDSS Stripe 82, the largest variability sample of quasars to date, by a power-law structure function we have illustrated how samples of quasar candidates with completeness and purity well above 90% is straightforwardly obtained. Applying our variability selection algorithm to data without *u*-band photometry that is crucial in color selection, as is the case for Pan-STARRS1 data, shows that variability selection of quasars is still capable

of selecting complete and pure quasar candidate samples. Variability selection of quasars out-performs the usual color selection at redshifts where quasars have the same colors as stars. We find that at z~2.7 variability selection of quasars is up to 10 times more effective than color selection. Not only does the intrinsic quasar variability aid in quasar selection, it also contains vital information about the quasar/AGN accretion disk physics, which still has to be fully understood. Through robust fitting, including outlier pruning, we determined the *color* variability of the ~9000 Stripe 82 quasars, i.e., the change of quasar color as their brightness changes on year time-scales. We found a strong redshift dependence of this color variability and showed that it is caused by the quasar's emission lines. Furthermore, we found that the characteristic color variability of the individual quasars is substantially stronger than the change of mean quasar color with L/L_{edd}, implying that changes in the overall accretion rate cannot explain the observed color variability.

109.04 – **Exploratory X-ray Monitoring of High Redshift Radio-Quiet Quasars**

Ohad Shemmer[1], W. N. Brandt[2], R. R. Gibson[3], S. Kaspi[4], D. P. Schneider[2], C. Vignali[5]

[1]*University of North Texas,* [2]*The Pennsylvania State University,* [3]*University of Washington,* [4]*Tel-Aviv University, Israel,* [5]*University of Bologna, Italy.*

10:40 AM - 10:50 AM

We present initial results from an exploratory X-ray monitoring of luminous, high redshift radio-quiet quasars (RQQs). This project consists of two groups of RQQs: 1) four sources at z~=4.2 monitored by *Chandra*, and 2) three sources at 1.3~<z~<2.7 monitored by *Swift*. The two groups have matched luminosities to disentangle the strong redshift-luminosity dependence. The prime goal of this project is to test claims that quasars were more X-ray variable in the early universe with implications for evolution scenarios of the central engine in active galactic nuclei. The X-ray monitoring is also supported by simultaneous or near-simultaneous UV-optical monitoring in order to search for potential correlated UV-optical and X-ray variations. The data will provide basic assessments of variability amplitudes and timescales that will allow planning of more ambitious and systematic X-ray monitoring of such distant RQQs with future X-ray missions.

109.05 – **The Two-Component Radio Luminosity Function of QSOs: Star Formation and AGNs**

Amy E. Kimball[1], K. I. Kellermann[1], J. J. Condon[1], Z. Ivezic[2], R. A. Perley[1]

[1]*NRAO,* [2]*University of Washington.*

10:50 AM - 11:00 AM

Despite decades of study, it remains unclear whether or not the radio emission from QSOs is bimodal consisting of distinct radio loud and radio quiet populations. Earlier studies were limited by inhomogeneneous QSO samples, inadequate sensitivity to fully sample the radio quiet population, degeneracy between redshift and luminosity for flux density limited samples, and strong evolution over the wide range of observed redshifts. Our new 6 GHz EVLA observations allow us for the first time to obtain nearly complete (97%) radio detections in a volume-limited, homogeneously-selected sample of 179 QSOs (Mi<-23) from the SDSS in the narrow redshift range $0.2 < z < 0.3$. With the dramatic improvement in radio continuum sensitivity with the EVLA, we were able to detect sources as faint as 20 microJy in just 35 minutes of observing time. This is equivalent to $L_{6GHz} = 10^{21.5}$ W/Hz at z=0.25, which is well below the radio luminosity ($L_{6GHz} = 10^{22.5}$ W/Hz) that separates star-forming galaxies from radio-loud AGNs driven by accretion onto a super-massive black hole. We will present the radio luminosity function (RLF) for these QSOs, constrained by our EVLA observations and by the total number of SDSS QSOs in the volume-limited sample, and will show that the RLF can be explained as a super-position of two populations, dominated by AGNs at the bright end and star-formation in the QSO host galaxies at the faint end.

109.06 – **The Evolution and Radio Luminosity Function of of Radio Quiet AGN**

Kenneth I. Kellermann[1], P. Padovani[2], N. Miller[3], A. Kimball[1], CDFS Group, EVLAQUASAR Group

[1]*NRAO,* [2]*ESO, Germany,* [3]*University of Md..*

11:00 AM - 11:10 AM

Using radio, x-ray, optical, FIR and NIR observations we have classified the radio emission from QSOs and galaxies found in 1.4 GHz VLA observations of the Chandra Deep Field South. We use the radio and optical morphology, optical spectroscopy, and IR colors, as well as comparing radio, x-ray, and optical luminosity to separate AGN and star formation driven radio emission from galaxies and QSOs (Padovani et al. 2011, ApJ, 740, 20). The sub-millijansky sky appears to contain a complex mix of star-forming galaxies, low luminosity AGN driven radio galaxies, as well as a previously unrecognized population of radio sources due to star formation from the hosts of radio-quiet QSOs which is also reported by Kimball et al. (2011, ApJL, 739, 29) from EVLA observations of quasars found in the SDSS. New observations by Miller et al. (2008, ApJS, 179, 114, and in preparation) made with a mosaic of six VLA pointings reach an rms sensitivity of 7 microJy over most of the CDFS. Combined with additional optical, IR and x-ray data, the new radio data will improve the determination of radio luminosity functions and their evolution which is made more complex by the emerging evidence that radio emission from both star formation and AGN coexist in both quasars and galaxies in varying amounts.

109.07D – **Variability Constraints on Quasar Broad Absorption Line Outflows**

Daniel M. Capellupo[1], F. Hamann[1], J. C. Shields[2], T. A. Barlow[3], J. P. Halpern[4], P. Rodriguez Hidalgo[5]

[1]*University of Florida,* [2]*Ohio University,* [3]*California Institute of Technology,* [4]*Columbia University,* [5]*Pennsylvania State University.*

11:10 AM - 11:30 AM

Broad absorption lines (BALs) in quasar spectra identify high velocity outflows that likely exist in all quasars and could play a major role in feedback to galaxy evolution. Studying the variability in these BALs can help us understand the structure, evolution, and basic physical properties of these outflows. We are conducting a BAL monitoring program, which so far includes 163 spectra of 24 luminous quasars at z=1.2-2.9, covering time-scales from ~1 week to 8 years in the quasar rest-frame. We investigate changes in both the CIV λ1550 BALs and the SiIV λ1400 BALs, and we see a variety of phenomena, including some BALs with dramatic variability over a wide range in outflow velocities and other BALs that did not change at all over the entire observation period. Variability generally occurred in only portions of BAL troughs. The fraction of quasars with CIV BAL variability increased as we added more observing epochs to our sample, with 88% of the quasars showing CIV BAL variability. When comparing CIV to SiIV BAL variability, we found that SiIV BALs are more likely to vary than CIV BALs. When both the CIV and SiIV BALs vary within the same quasar, they always vary in the same sense (with both lines either getting stronger or weaker). We have new data that probe the shortest time-scales (<1 month rest-frame), which provide constraints on the sizes and location of the outflowing gas. We also present some preliminary results on the study of key diagnostic lines, such as PV λ1118, 1128. Studying these lines provides crucial constraints on the total column densities in the flows, which we can then use to estimate their mass outflow rates and kinetic energy yields. These quantities will help determine the viability of these outflows as a feedback mechanism.

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110 – Extrasolar Planets: Habitable Zones

Oral Session – Ballroom F – Monday, January 9, 2012, 10:00 AM - 11:30 AM

110.01 – **Eta-Sub-Earth Projection from Kepler Data**

Wesley A. Traub[1]

[1]*Jet Propulsion Laboratory.*

10:00 AM - 10:10 AM

The exoplanet database from Kepler is examined for internal evidence of statistical completeness in terms of the radius, period, and type of exoplanet, as well as stellar host properties. Apparent limits on completeness, and apparent biases, are identified. The data are examined for evidence of statistical trends. The data are extrapolated to form a preliminary estimate of eta-sub-Earth, the frequency of terrestrial planets in the habitable zones of stars like the Sun.

110.02D – **Characterization of Exoplanet Atmospheres and Kepler Planet Candidates with Multi-Color Photometry from the Gran Telescopio Canarias**

Knicole Colon[1], E. B. Ford[1]

[1]*University of Florida.*

10:10 AM - 10:30 AM

With over 180 confirmed transiting exoplanets and NASA's Kepler mission's recent discovery of over 1200 transiting exoplanet candidates, we can conduct detailed investigations into the (i) properties of exoplanet atmospheres and (ii) false positive rates for planet search surveys. To aid these investigations, we developed a novel technique of using the Optical System for Imaging and low Resolution Integrated Spectroscopy (OSIRIS) installed on the 10.4-meter Gran Telescopio Canarias (GTC) to acquire near-simultaneous multi-color photometry of (i) HD 80606b in bandpasses around the potassium (K I) absorption feature, (ii) GJ 1214b in bandpasses around a possible methane absorption feature and (iii) several Kepler planet candidates. For HD 80606b, we measure a significant color change during transit between wavelengths that probe the K I line core and the K I wing, equivalent to a ~4.2% change in the apparent planetary radius. We hypothesize that the excess absorption may be due to K I in a high-speed wind being driven from the exoplanet's exosphere. This is one of the first detections of K I in an exoplanet atmosphere. For GJ 1214b, we compare the transit depths measured "on" and "off" a possible methane absorption feature and use our results to help resolve conflicting results from other studies regarding the composition of this super-Earth-size planet's atmosphere. For Kepler candidates, we use the color

change during transit to reject candidates that are false positives (e.g., a blend with an eclipsing binary either in the background/foreground or bound to the target star). We target small planets (<6 Earth radii) with short orbital periods (<6 days), since eclipsing binaries can mimic planets in this regime. Our results include identification of two false positives and test recent predictions of the false positive rates for the Kepler sample. This research demonstrates the value of the GTC for exoplanet follow-up.

110.03 – **On The Existence Of Earth-like Planets In The Circumbinary System Kepler-16**

Billy L. Quarles[1], Z. E. Musielak[1], M. Cuntz[1]

[1]*UTA.*

10:30 AM - 10:40 AM

The newly discovered circumbinary system Kepler-16 contains a pair of low-mass stars and a Saturn-mass planet (Doyle et al. 2011) [Science 333, 1602]. A truly fascinating problem is to explore whether Earth-like planets can exist in the habitable zone (HZ) of this unique system. The HZ of this system is mainly due to the primary star and extends from 0.36 AU to 0.71 AU. We have performed extensive numerical studies of long-term orbital stability of Earth-like planets in this HZ by considering both S-type and P-type planetary orbits. The semi-major axis for S-type orbits has been determined as 0.0675 ± 0.0039 AU from the stellar primary. This distance is well inside the inner limit of habitability where the influence of the runaway greenhouse effect becomes important. Consequently, the existence of a habitable Earth-like planet in an S-type orbit is highly unlikely. However it appears possible that such a planet can exist in a P-type orbit inside the HZ thus providing a realistic possibility for long-term evolution of life in this type of system. The obtained results are of special interest because they can assist in the selection process of system candidates in future terrestrial planet search missions.

110.04 – **Constraining the Mass, Age, and Orbital Architecture of HR 8799 Planetary System**

Nader Haghighipour[1], J. Sudol[2]

[1]*Univ. of Hawaii,* [2]*West Chester University.*

10:40 AM - 10:50 AM

The planetary system of HR 8799 represents a unique astrophysical laboratory in the sense that it is the only system for which direct images of multiple planets are currently available. The age of this system is critical to understanding how its planets formed and in calibrating the age-luminosity relationship for sub-stellar objects. The masses and orbital architecture of these planets (in particular their orbital inclinations) are also crucial in determining the most viable mechanism for the formation of these bodies. Current estimates suggest that the age of HR 8799 system is between 30 and 160 Myr with an orbital inclination ranging from 0° to 30°. This uncertainty in the age and orbital inclination, combined with the recent release of additional astrometric data, prompted us to examine the plausibility of the proposed orbital architecture of this system. We have carried out over 1.5 million simulations of the orbital stability of the four planets of HR 8799 for planetary masses ranging 7 to 10 Jupiter-masses and orbital inclinations ranging from 0° to 30°. Results of our simulations impose strong constraints on the orbital architecture of this system and indicate that the longest lifetimes of the planets at 0°, 13°, and 18° are less than 30 Myr. This finding implies that at these angles, the system of HR8799 is young and its planetary masses are smaller than 7-10-10-10 Jupiter-masses. Among all our models, the one with a 30° inclination has the longest lifetime of 122 Myr suggesting that at this inclination, an older system would be permitted with higher mass planets. We present the details of our study and discuss the implications of the results for constraining the mass and inclination of the system as well as possible models of its formation.

110.05 – **The GJ 876 System: Fundamental Stellar Parameters and Planets in the Habitable Zone**

Kaspar von Braun[1], T. S. Boyajian[2], J. Jones[2], S. R. Kane[1], S. N. Raymond[3], G. T. van Belle[4], D. R. Ciardi[1], M. Lopez-Morales[5], T. A. ten Brummelaar[6], H. A. McAlister[2], G. Schaefer[6], S. R. Ridgway[7], J. Sturmann[6], L. Sturmann[6], N. H. Turner[6], C. Farrington[6], P. J. Goldfinger[6]

[1]*Caltech,* [2]*Georgia State University,* [3]*Bordeaux, France,* [4]*Lowell,* [5]*CSIC-IEEC, Spain,* [6]*CHARA Array,* [7]*NOAO.*

10:50 AM - 11:00 AM

GJ 876 is a nearby M dwarf hosting four currently known extrasolar planets. We use the CHARA interferometric array to determine the stellar angular diameter. Coupled with trigonometric parallax values and literature photometry, we obtain direct estimates of the stellar physical size, surface temperature, luminosity, and location / extent of the system's habitable zone (HZ). We present our measurement results of the GJ 876 stellar astrophysical parameters and the location of the HZ relative to the planetary orbits.

110.06 – **55 Cancri: A Coplanar Planetary System that is Likely Misaligned with its Star**

Nathan A. Kaib[1], S. N. Raymond[2], M. J. Duncan[1]

[1]*Queen's University, Canada,* [2]*Universite de Bordeaux, France.*

11:00 AM - 11:10 AM

Most mechanisms invoked to explain the high spin-orbit angles observed for some transiting planets require them to pass through a phase of extremely high orbital eccentricity. This would seem to preclude high spin-orbit angles in systems with multiple, coplanar planets on circular orbits, since these mechanisms would produce planet-planet scattering. Although the 55 Cnc system contains such well-ordered planets, we use numerical simulations to demonstrate that they too are likely to be highly inclined to their parent star's spin axis. Due to perturbations from its distant binary companion, this planetary system precesses like a rigid body about its parent star (without exciting the planets' eccentricities). Consequently, the parent star's spin axis and the planetary orbit normal likely diverged long ago. We predict that the most likely projected spin-orbit angle is ~50 degrees, with a ~30% chance of a retrograde configuration. Transit observations of the innermost planet - 55 Cnc e - may be used to test these predictions via the Rossiter-McLaughlin effect. 55 Cancri may thus represent a new class of planetary systems with well- ordered, coplanar orbits that are inclined with respect to the stellar equator. This work was funded by a CITA National Fellowship and Canada's NSERC. SNR thanks the CNRS's PNP program and the NASA Astrobiology Institute's Virtual Planetary Laboratory team.

110.07 – **Orbital Motion Of HR 8799 b, c, d Using Hubble Space Telescope Data From 1998: Constraints On Inclination, Eccentricity And Stability**

Remi Soummer[1], J. B. Hagan[1], L. Pueyo[1], A. Thormann[2], A. Rajan[1], C. Marois[3]

[1]*Space Telescope Science Institute,* [2]*Johns Hopkins University,* [3]*NRC Herzberg Institute of Astrophysics, Canada.*

11:10 AM - 11:20 AM

HR 8799 is currently the only multiple-planet system that has been detected with direct imaging, with four giant planets orbiting at large separations from this young late A star. Orbital motion provides insight into the stability, and possible formation mechanisms of this planetary system. Dynamical studies can also provide constraints on the planets' masses, which help calibrate evolutionary models. Yet, measuring the orbital motion is a very difficult task because the long-period orbits (50-500 yr) require long time baselines and high-precision astrometry. We study the three planets HR 8799b, c and d in the archival data set of HR 8799 obtained with the Hubble Space Telescope (HST) NICMOS coronagraph in 1998. The detection of all three planets is made possible by a careful optimization of the LOCI algorithm, and we used a statistical analysis of a large number of reduced images. This work confirms previous astrometry for planet b, and presents new detections and astrometry for c and d. These HST images provide a ten-year baseline with the discovery images from 2008, and therefore offer a unique opportunity to constrain their orbital motion now. Recent dynamical studies of this system show the existence of a few possible stable solutions involving mean motion resonances, where the interaction between c and d plays a major role. We study the compatibility of a few of these stable scenarios (1d:1c, 1d:2c, or 1d:2c:4d) with the new astrometric data from HST. Our results are consistent with previously published results based on dynamical studies for a three-planet system prior to the discovery of the fourth planet.

110.08 – **Studying Photometric Orbital Modulations Of Kepler Objects Of Interest**

Avi Shporer[1], B. J. Fulton[2], Kepler team

[1]*University of California, Santa Barbara,* [2]*Las Cumbres Observatory Global Telescope.*

11:20 AM - 11:30 AM

Kepler high precision measurements allow the detection of the minute photometric modulations correlated with the orbit, induced by low-mass companions down to the planetary mass range. Those modulations include the beaming effect, tidal ellipsoidal distortion, and reflection or heating of the companion. They represent an opportunity to study these systems in detail using Kepler photometry alone. For transiting systems the known ephemeris allows a more accurate measurement of the orbital modulations amplitude. I will present results from a search for photometric orbital modulations, including the beaming effect, in short-period Jupiter-mass transiting planets.

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111 – Evolution of Galaxies I

Oral Session – Room 18C – Monday, January 9, 2012, 10:00 AM - 11:30 AM

111.01 – **Lyman Alpha Emission Line Profile From Local Star-forming Galaxies**

Claudia Scarlata[1]

[1]*University of Minnesota.*

10:00 AM - 10:10 AM

With the aim of characterizing the physics of Lyman alpha (Lya) escape from galaxies, we have undertaken a major effort to followup a well-defined sample of GALEX-selected z~0.3 Lya emitters. Here, we present results based on new FUV COS-G160M spectroscopy of 25 GALEX star-forming Lya emitters. We present resolved Lya profiles and compare the results with resolved profiles obtained from galaxies in the distant universe.

111.02 – **The Kinematics of Multiple-Peaked Lyα Emission in Star-Forming Galaxies at z ~ 2 − 3**

Kristin Kulas[1], A. E. Shapley[1], J. A. Kollmeier[2], Z. Zheng[3], C. C. Steidel[4], K. N. Hainline[1]

[1]UC Los Angeles, [2]Observatories of the Carnegie Institution of Washington, [3]Yale Center for Astronomy and Astrophysics, [4]California Institute of Technology.
10:10 AM - 10:20 AM

We present new results on the Lyα emission-line kinematics of 18 z ~ 2 − 3 star-forming galaxies with multiple-peaked Lyα profiles. With our large spectroscopic database of UV-selected star-forming galaxies at these redshifts, we have determined that ~30% of such objects with detectable Lyα emission display multiple-peaked emission profiles. These profiles provide additional constraints on the escape of Lyα photons due to the rich velocity structure in the emergent line. Despite recent advances in modeling the escape of Lyα from star-forming galaxies at high redshifts, comparisons between models and data are often missing crucial observational information. Using Keck II NIRSPEC spectra of Hα (z ~ 2) and [OIII]λ5007 (z ~ 3), we have measured accurate systemic redshifts, rest-frame optical nebular velocity dispersions and emission-line fluxes for the objects in the sample. Accurate systemic redshifts allow us to translate the multiple-peaked Lyα profiles into velocity space, revealing that the majority (11/18) display double-peaked emission straddling the velocity-field zeropoint with stronger red-side emission. Interstellar absorption-line kinematics suggests the presence of large-scale outflows for the majority of objects in our sample. A comparison of the interstellar absorption kinematics for objects with multiple- and single-peaked Lyα profiles indicate that the multiple-peaked objects are characterized by significantly narrower absorption line widths. We compare our data with the predictions of simple models for outflowing and infalling gas distributions around high-redshift galaxies. While popular “shell” models provide a qualitative match with many of the observations of Lyα emission, we find that in detail there are important discrepancies between the models and data, as well as problems with applying the framework of an expanding thin shell of gas to explain high-redshift galaxy spectra. Our data highlight these inconsistencies, as well as illuminating critical elements for success in future models of outflow and infall in high-redshift galaxies.

111.03D – **Stellar Populations And Galactic Outflows At z ~ 3**

Emily McLinden[1], J. E. Rhoads[1], S. Malhotra[1], S. L. Finkelstein[2], P. Hibon[3], M. L. A. Richardson[1]

[1]Arizona State University, [2]University of Texas, [3]Gemini, Chile.
10:20 AM - 10:40 AM

We have measured a velocity offset between the Lyman-α emission line and the [OIII] nebular emission line in three spectroscopically confirmed z ~ 3.1 Lyman-α emitting galaxies (LAEs). Such velocity offsets indicate the presence of powerful outflows in these galaxies. We made these measurements by combining near-infrared spectroscopy of the [OIII] line (from LBT/LUCIFER) with optical spectroscopy of the Lyman-α line (from MMT/Hectospec). We contend that tracing the kinematics of these galaxies is crucial for understanding how the prominent Ly-α emission from these galaxies is produced and how it escapes. LAEs are an exciting tool for studying the early universe, as Lyman-α emission is a prominent sign of young star forming galaxies at high redshift. It can be used to identify galaxy samples with characteristic continuum luminosities and stellar masses well below those typically obtained from Lyman break selection or other high-redshift galaxy search methods.

To further understand what these young, low-mass objects tell us about galaxy formation, assembly, and evolution we have used our NIR spectroscopic data to demonstrate how the [OIII] emission line in the K_S filter alters SED fitting results of our z ~ 3.1 LAEs. This information allows us to produce more accurate SED fits of those LAEs with NIR data, and predict [OIII] line fluxes in those LAEs that have yet to be observed in the NIR. Our SED fitting sample of ~ 30 confirmed z ~ 3.1 LAEs is one of the largest produced to date and provides a powerful look at accurate ages, masses, metallicities, dust characteristics and star formation histories of these early galaxies.

111.04 – **Dynamical and Stellar Masses of Lyman-alpha Galaxies**

James E. Rhoads[1], S. Malhotra[1], E. McLinden[1], M. L. Richardson[1], S. L. Finkelstein[2], V. S. Tilvi[3]

[1]Arizona State Univ., [2]University of Texas, [3]Texas A&M Univeristy.
10:40 AM - 10:50 AM

We have observed strong nebular lines of [OIII] and H alpha for Lyman-alpha galaxies at z=2-3.1 using Keck+NIRSPEC, LBT+LUCIFER, and Gemini+NIFS. [OIII] 5007 is strong enough to dominate the 2 micron K band fluxes of these galaxies, and leads to an overestimate of the stellar mass of the galaxy by an order of magnitude. After correcting for the observed [OIII] lines, we infer low masses and young ages for these galaxies. We also use the physical widths of the rest-optical lines, combined with spatial sizes from HST imaging, to obtain direct dynamical mass estimates of Lyman alpha galaxies (which cannot be done using the resonantly scattered Lyman alpha line). Finally, we combine our stellar mass estimates and line widths to place these galaxies on the baryonic Tully-Fisher relation. We find that the stellar masses required to reproduce the observed light are lower than one would expect based on the galaxies' line widths. The stellar mass densities of these galaxies are comparable to those of elliptical galaxies today.

We gratefully acknowledge support from NSF grant NSF-AST-0808165.

111.05D – **The Ultraviolet Spectra of Lyman Break Galaxies at z=4**

Tucker Jones[1], D. Stark[2], R. Ellis[1]

[1]California Institute of Technology, [2]University of Arizona.
10:50 AM - 11:10 AM

Outflowing winds of gas and dust are important in regulating the star formation rate and metallicity of galaxies, enriching the intergalactic medium, and determining the escape fraction of Lyα and ionizing photons. We present results from a deep rest-frame ultraviolet spectroscopic survey of Lyman break galaxies (LBGs) at 3 < z < 7 focusing on the mean outflow properties at z=4. Composite spectra of LBGs are used to measure trends in low-ionization absorption lines, which arise in neutral outflowing gas. We compare these results with previous studies at z=3 and find that our sample at z=4 follows the same trends. Specifically, galaxies with fainter UV luminosities, bluer UV spectral slopes, lower stellar masses, and smaller half-light radii show on average weaker low-ionization absorption lines and stronger Lyα emission. The weaker absorption lines indicate a decrease in the covering fraction and/or velocity range of outflowing neutral gas, which in turn enables a higher escape fraction of Lyα photons. LBGs at z=4 show somewhat weaker low-ionization absorption and stronger Lyα than at z=3, consistent with differences in the average demographic properties. We expect galaxies at higher redshifts to show even stronger Lyα emission and weaker low-ionization absorption, based on the observed trends and the average demographics of high-redshift LBGs. We discuss these results in the context of the measured fraction of LBGs with strong Lyα emission at 3 < z < 8.

111.06 – **Lyman-alpha Emitters At Redshift Z~4.5 In The Extended CDF-S Region: Luminosity Functions, Clustering And Lyman-alpha EW Distribution.**

Zhenya Zheng[1], S. Malhotra[1], J. Rhoads[1], J. Wang[2], S. Finkelstein[3], V. Tilvi[1], K. Finkelstein[3]

[1]Arizona State University, [2]University of Science and Technology of China, China, [3]Texas A&M University.
11:10 AM - 11:20 AM

We present a spectroscopically confirmed Lyman alpha emitter(hereafter LAE) samples at z~4.5 in the Extended Chandra Deep Field South region. With this sample, we analyze the 1) Lyman-alpha Luminosity functions; 2) spatial clustering; and 3) Lyman-alpha Equivalent Width distributions for photometric LAE candidates and confirmed LAEs at redshift z~4.5. The Lyman-alpha luminosity function and spatial clustering for our z ~ 4.5 sample is

consistent with others published in the literature during the redshift range of 3 < z < 6, while

the Lyman-alpha luminosity functions in our two separate narrowband filters show a ~ 2 Sigma difference. The difference is comparable to differences among z=5.7 and z=6.5 LyA luminosity functions.

We also did a Monte Carlo simulation of the Lyman-alpha equivalent width distribution. We found that the Lyman-alpha EW is independent of the Lyman-alpha line luminosity, and its distribution shows an exponential form.We gratefully acknowledge support from NSF grant NSF-AST-0808165.

111.07 – **X-ray Study of Galaxy Evolution from Infancy to Mid-Life: What the Deepest X-ray Stacking of 1<z<4 Star-forming Galaxies Reveals**

Antara Basu-Zych[1], B. Lehmer[2], A. Hornschemeier[1], R. Bouwens[3], N. Brandt[4], P. Oesch[5]

[1]Goddard Space Flight Center, [2]Johns Hopkins University, [3]Leiden, Netherlands, [4]Penn State University, [5]UC Santa Cruz.
11:20 AM - 11:30 AM

We present early results from the deepest X-ray stacking of >5000 high redshift galaxies from z=1 to 8 using the recently acquired Chandra Deep Field South (CDF-S) 4Ms data. The galaxy samples were selected using the Lyman break technique based on recent HST ACS and WFC3 observations. Based on the X-ray stacking analyses for the 1<z<4 LBGs, we find that the mean L_X/SFR ratio remains roughly constant, consistent with X-ray binary population synthesis models. We do not obtain significant X-ray detections from stacking LBGs at z ~ 6, 7, and 8 and obtain upper limits that are inconsistent with recently published results, constraining the SMBH accretion history of the Universe.

112 – Dark Matter & Dark Energy

Oral Session – Ballroom G – Monday, January 9, 2012, 10:00 AM - 11:30 AM

112.02 – **Astronomical Constraints on Quantum Cold Dark Matter**

Shane Spivey[1], Z. Musielak[1], J. Fry[1]

[1]*University of Texas at Arlington.*

10:10 AM - 10:20 AM

A model of quantum ('fuzzy') cold dark matter that accounts for both the halo core problem and the missing dwarf galaxies problem, which plague the usual cold dark matter paradigm, is developed. The model requires that a cold dark matter particle has a mass so small that its only allowed physical description is a quantum wave function. Each such particle in a galactic halo is bound to a gravitational potential that is created by luminous matter and by the halo itself, and the resulting wave function is described by a Schrödinger equation. To solve this equation on a galactic scale, we impose astronomical constraints that involve several density profiles used to fit data from simulations of dark matter galactic halos. The solutions to the Schrödinger equation are quantum waves which resemble the density profiles acquired from simulations, and they are used to determine the mass of the cold dark matter particle. The effects of adding certain types of baryonic matter to the halo, such as a dwarf elliptical galaxy or a supermassive black hole, are also discussed.

112.03 – **Dark Matter Annihilation and the Origin of Synchrotron Radio Emission from the Galactic Center Filaments**

Farhad Yusef-Zadeh[1], T. Linden[2], D. Hooper[3]

[1]*Northwestern Univ.,* [2]*UC Santa Cruz,* [3]*Fermilab.*

10:20 AM - 10:30 AM

Over the last two decades radio continuum observations of the Galactic center region have revealed a large number of nonthermal radio filaments within the inner two degrees of the Galactic center. Theoretically, it has been challenging to understand the nature of these filaments which appear not to be accompanied by any obvious source of acceleration of charged particles to high energy relativistic energies. WIMPs have been considered as an explanation for observations indicating non-baryonic matter density peaking at the Galactic center. Here,we propose that the electrons and positrons created through the annihilation of a relatively light (~5-10 GeV) dark matter particle can provide a reasonable match to the intensity and spectral shape of radio filaments at the Galactic center.

112.04 – **Is Dark Matter a purely Geometric Effect Within the Einstein Equations?**

Harry I. Ringermacher[1], L. R. Mead[2]

[1]*General Electric Research Ctr.,* [2]*Dept. of Physics, University of Southern Mississippi.*

10:30 AM - 10:40 AM

In MNRAS 397,164 (2009) we introduced a new formula that describes the natural pitch variation of all spiral galaxy types using a single shape parameter Φ. $r(\phi) = R/(1-\Phi\tan\Phi \log[\phi/\Phi])$. What was not stated was that this formula was derived from a solution of the Einstein equations for a new geometric model of dark matter. The Einstein equations responded to the question: "Can matter density be replaced instead by a simple geometry?" The answer was: "Yes, described approximately by a quasi-static negatively-curved 3-space embedded in a nearly-flat 4-dimensional pseudosphere. We call the metric of this space CRW (for Cancel Robertson-Walker). We can show that this space results in stellar motions that account for many arduously derived galactic phenomena including; precise spiral structure, RCs, symmetries, galaxy-type abundances, galactic warping, polar rings and more. There are signature predictions as well. All of these results derive from the unusual orbit behavior permitted in hyperbolic spaces that seem to emulate the properties of dark matter. We will present some insights.

112.05D – **Simulating Error in Cluster Weak Lensing Tomography**

Kellen J. Murphy[1]

[1]*Ohio University.*

10:40 AM - 11:00 AM

We present the results of an N-body simulation of the various sources of systematic error in constraining the dark energy equation of state via cluster weak lensing tomography. The use of tomographic techniques to constrain the dark energy equation of state parameter is a pivotal component of future large survey missions, however, the application of tomography to cosmic shear necessitates the exclusion of regions around galaxy clusters from analysis. We therefore test the applicability tomography to cluster-induced shear as a secondary, complementary sample through which estimates of the dark energy e.o.s. parameter can be made. Furthermore, we demonstrate the application of this technique to a test sample of 10 massive galaxy clusters imaged by the Hubble Space Telescope.

112.06 – **ISiTGR: A Software Package for Testing General Relativity at Cosmological Scales.**

Jason Dossett[1], M. Ishak[1], J. Moldenhauer[2]

[1]*The University of Texas at Dallas,* [2]*Francis Marion University.*

11:00 AM - 11:10 AM

Motivated not only by the problem of cosmic acceleration, but also by the proposals of some extensions to general relativity that would manifest themselves at cosmological scales, the testing of general relativity at cosmological scales has gained increasing popularity. To help test the consistency of general relativity and other gravity theories with current and future data, we introduce the package ISiTGR: **I**ntegrated **S**oftware **i**n **T**esting **G**eneral **R**elativity. ISiTGR is an integrated set of modified modules for the publicly available packages CosmoMC and CAMB, including a modified version of the ISW-galaxy cross correlation module of Ho et al and a new weak-lensing likelihood module for the refined HST-COSMOS weak gravitational lensing tomography data. We review recently proposed approaches to evolving the modified growth parameters as well as our newly proposed method that avoids some common problems of those approaches. We give some results to illustrate the use of ISiTGR.

113 – Cyber-Discovery and Science for the Decade

Special Session – Room 18D – Monday, January 9, 2012, 10:00 AM - 11:30 AM

The goal of the session is to highlight the science that is driving large surveys and instruments with high data rates, and how meaning can be extracted from the resulting large data sets. The session seeks to illustrate the sense of Cyber-Discovery that will become possible in this decade---as discussed in the New Worlds, New Horizons Decadal Survey.
The structure of the session will be as a series of invited talks, with topics including time domain surveys, testing fundamental physics via radio pulsar observations, cosmological simulations, and machine learning techniques that could apply for astronomical data processing. Speakers will discuss not only the science, but illustrate how the science pushes the envelope in some aspect or aspects of "big data."

113.01 – **Finding and Classifying Variables and Transients in the LSST Data Stream**

Lucianne M. Walkowicz[1]

[1]*Princeton University.*

10:00 AM - 10:20 AM

LSST's all-sky coverage, consistent 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 objects both familiar and exotic, from known types of variables in the local universe, to rare and faint transients at cosmological distances. Increased sample sizes of known-but-rare observational phenomena will quantify their distributions for the first time, thus challenging existing theory. LSST will also sample regions of parameter space where transient events are expected on theoretical grounds, but have not yet been observed. These scientific opportunities necessarily come with new challenges: in the vast LSST data stream, how does one identify events of interest, and marshal precious observational resources to study these events in detail? In this talk, I discuss both the opportunities LSST will provide, as well as the challenges we face and opportunities for community involvement.

113.02 – **Petabytes and Basic Physics: Today's Surveys for Exotic Pulsars**

Scott M. Ransom[1]

[1]*NRAO.*

10:20 AM - 10:40 AM

The future of much of astronomy is in high data-volume surveys, many of which will generate Petabytes of data. Pulsar astronomers have been generating such data volumes for the past five years or so in their quests to find (primarily) faint radio millisecond pulsars which are useful for a variety of basic physics "experiments". While the surveys themselves are quite specific in their desired outcomes (i.e. new pulsars), the data products are fairly generic and could be used for other science purposes (i.e.

fast radio transients, high-redshift HI absorption line studies...). Given that these very large datasets are produced on National facilities, it is interesting to ask, therefore, whether they should all be archived and made available for everyone. And if so, at what cost? In this talk I'll mention some of the science that we are after in these surveys, some of the logistical difficulties we have dealing with hundreds of TB of data with only small teams, and possible non-pulsar uses of such surveys.

113.03 – **Extreme Data-Intensive Computing in Astrophysics**

Alexander S. Szalay[1]

[1]*Johns Hopkins Univ..*
10:40 AM - 11:00 AM

Scientific computing is increasingly revolving around massive amounts of data. From physical sciences to numerical simulations, we are soon dealing with Petabytes if not Exabytes of data. This new, data-centric computing requires a new look at computing architectures and strategies for statistical analyses. Several large-scale data analysis projects in astronomy and physics will be discussed, including statistical analyses of large galaxy catalogs. We will also explore strategies of interacting with very large amounts of data, and compare various large-scale data analysis platforms.

113.04 – **On-line Machine Learning and Event Detection in Petascale Data Streams**

David R. Thompson[1], K. L. Wagstaff[1]

[1]*JPL.*
11:00 AM - 11:20 AM

Traditional statistical data mining involves off-line analysis in which all data are available and equally accessible. However, petascale datasets have challenged this premise since it is often impossible to store, let alone analyze, the relevant observations. This has led the machine learning community to investigate adaptive processing chains where data mining is a continuous process. Here pattern recognition permits triage and followup decisions at multiple stages of a processing pipeline. Such techniques can also benefit new astronomical instruments such as the Large Synoptic Survey Telescope (LSST) and Square Kilometre Array (SKA) that will generate petascale data volumes. We summarize some machine learning perspectives on real time data mining, with representative cases of astronomical applications and event detection in high volume datastreams.

The first is a "supervised classification" approach currently used for transient event detection at the Very Long Baseline Array (VLBA). It injects known signals of interest - faint single-pulse anomalies - and tunes system parameters to recover these events. This permits meaningful event detection for diverse instrument configurations and observing conditions whose noise cannot be well-characterized in advance. Second, "semi-supervised novelty detection" finds novel events based on statistical deviations from previous patterns. It detects outlier signals of interest while considering known examples of false alarm interference. Applied to data from the Parkes pulsar survey, the approach identifies anomalous "peryton" phenomena that do not match previous event models. Finally, we consider online light curve classification that can trigger adaptive followup measurements of candidate events. Classifier performance analyses suggest optimal survey strategies, and permit principled followup decisions from incomplete data. These examples trace a broad range of algorithm possibilities available for online astronomical data mining.

This talk describes research performed at the Jet Propulsion Laboratory, California Institute of Technology.

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114 – The Milky Way: Structure and Assembly

Oral Session – Ballroom D – Monday, January 9, 2012, 10:00 AM - 11:30 AM

114.01 – **Astrophysics with Kepler During an Extended Mission**

Martin D. Still[1]

[1]*NASA Ames Research Center.*
10:00 AM - 10:10 AM

Kepler's primary scientific focus is an exoplanet survey, yet publications from the Kepler community are dominated in number by astrophysics. Kepler provides high-precision photometry, a 116 sq. deg. FOV, near-monatonic cadence, 3 years of continuous observing and a >92% duty cycle. Individually, none of these characteristics are unique, but collectively they are a unique and powerful resource. Fundamental questions that can and should be tackled by an open, community driven effort during mission extension are: what are the physical conditions internal and external to stars in our galactic neighborhood? How do those physical conditions drive stellar behavior? Hold old are the stars in our neighborhood? How does stellar behavior and age impact exoplanet physics and the development of ecosystems? Is the sun a typical or atypical star? What impact does this have for solar system phsics and life on Earth? Kepler's "tool kit" for answering these questions is dominated by asteroseismology, magnetic activity, gyrochronology, and binary stars.

An 8 year mission will allow Kepler to monitor complete dynamo cycles in thousands of stars. While the longer baselines and critical innovations in Kepler data analysis will combine to test how typical the sun is over timescales from a few hours to many years. It is predicted that the Kepler community will be able to age stars using rotation rate as a proxy, calibrated against the 4 open clusters of known age in the field. Longer baselines provide sensitivity to lower levels of spot activity, pushing our ability to age increasingly older stars and their planets. For asteroseismology, the size of stellar ensembles will increase, the accuracy of stellar parameters will increase. Fainter pulsations will be detectable pushing asteroseismology in the regions of hotter and cooler stars. Asteroseismology will reveal potentially stellar rotation and differential rotation within stellar interiors.

114.02 – **Accurate Masses and Radii for Kepler's Multi-Eclipsing Hierarchical Triples**

Joshua A. Carter[1], Kepler Team

[1]*Smithsonian Astrophysical Observatory.*
10:10 AM - 10:20 AM

Dynamically interacting, multi-eclipsing hierarchical triples - observed with Kepler - have recently been shown to be amenable to detailed photo-dynamical modeling that yields surprisingly accurate masses and radii for all members in the system. These published systems harbor planets and very low-mass stars (e.g. the planet Kepler-16b and the stars Kepler-16 B, KOI-126 B and C) and have coevolved companions at large mass ratios (e.g. Kepler-16 A, KOI-126 A). As such, these systems are important benchmarks for stellar models in the poorly calibrated low-mass domain and for a wide range of masses. We report on the progress of a program to model and accurately characterize the remaining Kepler-identified stellar multi-eclipsing triple systems. This program has a simple goal: we will populate the stellar mass-radius diagram with accurate values so as to definitively judge the efficacy of stellar models.

114.03D – **Simulating the Past: Creating Testable Predictions of the Milky Way's Assembly History Using Numerical Experiments**

Jonathan C. Bird[1]

[1]*The Ohio State University.*
10:20 AM - 10:40 AM

Current and next generation surveys of the Milky Way promise to revolutionize our observational perspective of the Galaxy. My dissertation uses a suite of N-body and SPH simulations of disk galaxies to make testable predictions of the assembly history of the Milky Way and identify observational probes that take advantage of the forthcoming data. APOGEE, an infrared survey of the Galaxy and a component of the SDSS-III, will measure the distance, radial velocity, and multi-element chemistry of ~10^5 stars located throughout the Galaxy, making it particularly well suited for comparison with simulations. Our initial investigation explores how the minor mergers expected in Lambda-CDM and inherent properties of stellar disks affect the dynamics of stellar radial migration- an essential ingredient in understanding the evolution of the Milky Way and disk galaxies in general. We discover that the resonances and mechanisms responsible for migration are different in isolated and satellite-bombarded galaxies, resulting in distinct migration patterns and potential observational signatures of accretion events. Continuing our development of tools to describe the chemo-dynamics of the disk, we construct statistics to measure overdensities and characterize outliers in the distance, radial velocity projection of phase space. I discuss mock APOGEE observations of our numerical simulations and demonstrate that our statistics can discriminate between significant galaxy formation mechanisms given the data available in the near term. Galaxy formation theory faces the exciting challenge of an unprecedented level of statistical scrutiny: imminent and ongoing surveys such as SEGUE, RAVE, APOGEE, LAMOST, and HERMES offer an extraordinary opportunity to unravel the formation history of the Milky Way.

114.04D – **Smooth, Squashed And Rotating: Not The Stellar Halo We Used To Know**

Alis J. Deason[1], V. Belokurov[1], N. W. Evans[1]

[1]*University of Cambridge, United Kingdom.*
10:40 AM - 11:00 AM

The phase-space structure of the stellar halo is intimately linked to the formation history of the Galaxy. In this talk I will discuss the rotation properties and spatial structure of the stellar halo as traced by Blue Horizontal Branch (BHB) stars. Using SDSS spectroscopic data I find an apparent dichotomy between relatively metal-rich and metal-poor stars. I argue that a retrograde signal in the metal-poor stars is due to an underestimate of the Local Standard or Rest while the kinematic signature of the metal-rich stars may be linked to a (massive) accretion event. In addition, I introduce a new method to discern BHB stars from Blue Straggler stars using a colour dependent membership probability, thus circumventing the need for spectroscopic data. This new

method is applied to a sample of A-type stars selected from the latest SDSS DR8 photometric catalog. I find that the (inner) stellar halo is 'squashed, broken but smooth' and discuss the implications of this result. Finally, I compare these observational results to state-of-the-art cosmological simulations.

114.05D – **Using SEGUE Cool Stars to Examine the Metallicity Structure of the Milky Way Disk**

Katie Schlesinger[1]

[1]*University of California - Santa Cruz.*
11:00 AM - 11:20 AM

We utilize the spectroscopically observed stars from the SEGUE Survey to examine the metallicity structure of the Galactic disk. Previous analyses of the metallicity distribution function of cool stars in the disk relied on local samples consisting of hundreds of stars (Rocha-Pinto & Maciel 1998, Kotoneva et al. 2002). Utilizing SDSS, we can greatly increase the sample size and extent of the disk probed. We benefit from the quantitative and systematic target selection algorithm of SEGUE, which allows us to use our spectroscopic sample of 60,000 stars to reflect the properties of the underlying stellar populations. This is by far the largest analysis of the disk utilizing spectroscopic metallicities and will be particularly critical for understanding the chemical evolution of the Milky Way. Throughout the disk, we find good agreement between G and K dwarfs, indicating similar star formation histories. In addition, both are deficient in metal-poor stars when compared with a simple closed box model, the classic "G dwarf problem." The two spectral types also show a consistent decrease in [Fe/H] with respect to increasing |Z|. Comparison with thin and thick disk samples, defined by [α/Fe], from Lee et al. (2011) indicates that the vertical metallicity gradient reflects the transition in G and K dwarfs from a thin-disk-dominated sample at small |Z| to a sample consisting primarily of thick-disk stars at high |Z|.

114.06 – **Mining Hot, Luminous Stars in the Southern Sky: A New Look at the Magellanic-Cloud System**

Dana I. Casetti-Dinescu[1], K. Vieira[2], T. M. Girard[1], W. F. van Altena[1]

[1]*Yale Univ.,* [2]*CIDA, Venezuela, Bolivarian Republic of.*
11:20 AM - 11:30 AM

We have used absolute proper motions and V ccd photmetry from the Southern Proper Motion 4 (SPM4) catalog, combined with GALEX UV and 2MASS photometry to select candidate hot, luminous stars in the southern sky (dec < 20 deg). In areas where the SPM4 has only photographic V, we have supplemented our database with V ccd photometry from APASS - the AAVSO Photometric All Sky Survey - Data Release 3. We therefore explore an area of about 7900 square degrees, focusing on the magnitude range V = 13 to 16.5. With the aid of the proper motions, we

further distinguish kinematically different populations of nearby and distant stars. In particular OB-type members of the Magellanic Clouds and Bridge are mapped in areas not previously explored by photometric surveys. Besides the known and well-populated SMC wing, we find candidate OB stars in a path leading all the way from the wing to the LMC, and well-defined clumps in the LMC's periphery. Most of our candidates do not coincide spatially with the clusters and associations cataloged in the Clouds. The mapping of these types of stars will help us to understand the dynamical interaction between the

Clouds in the recent past.

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115 – HAD IV History of Astronomy

Oral Session – Room 12A – Monday, January 9, 2012, 10:00 AM - 11:30 AM

115.01 – **Discovery and Classification in Astronomy**

Steven J. Dick[1]

[1]*NASM.*
10:00 AM - 10:15 AM

Three decades after Martin Harwit's pioneering Cosmic Discovery (1981), and following on the recent IAU Symposium "Accelerating the Rate of Astronomical Discovery," we have revisited the problem of discovery in astronomy, emphasizing new classes of objects. 82 such classes have been identified and analyzed, including 22 in the realm of the planets, 36 in the realm of the stars, and 24 in the realm of the galaxies. We find an extended structure of discovery, consisting of detection, interpretation and understanding, each with its own nuances and a microstructure including conceptual, technological and social roles. This is true with a remarkable degree of consistency over the last 400 years of telescopic astronomy, ranging from Galileo's discovery of satellites, planetary rings and star clusters, to the discovery of quasars and pulsars. Telescopes have served as "engines of discovery" in several ways, ranging from telescope size and sensitivity (planetary nebulae and spiral galaxies), to specialized detectors (TNOs) and the opening of the electromagnetic spectrum for astronomy (pulsars, pulsar planets, and most active galaxies). A few classes (radiation belts, the solar wind and cosmic rays), were initially discovered without the telescope. Classification also plays an important role in discovery. While it might seem that classification marks the end of discovery, or a post-discovery phase, in fact it often marks the beginning, even a pre-discovery phase. Nowhere is this more clearly seen than in the classification of stellar spectra, long before dwarfs, giants and supergiants were known, or their evolutionary sequence recognized. Classification may also be part of a post-discovery phase, as in the MK system of stellar classification, constructed after the discovery of stellar luminosity classes. Some classes are declared rather than discovered, as in the case of gas and ice giant planets, and, infamously, Pluto as a dwarf planet.

115.02 – **Long-publishing Astronomers, or the Problem of Classification**

Joseph S. Tenn[1]

[1]*Sonoma State Univ..*
10:15 AM - 10:30 AM

In response to several discussions among astronomers and historians of astronomy, I started out to prepare a paper on long-publishing astronomers--those who published for 70, 75, or even 80 years. However, I soon ran into a number of questions of classification, and that turned out to be at least as interesting. How do we decide on classifications? Every time we choose classes, such as asteroids, planets and stars, we run into objects that seem to be in between. In the present case a number of questions arise: Who is an astronomer? Several of those with the longest publication runs started out as physicists, published for years in that subject only, and later took up astrophysics, eventually publishing a few (or even no) papers in astronomy journals. What is a publication? Should we count publications in physics, chemistry, or mathematics? What about philosophy of science or history of science? What about the elderly retired astronomer presenting a memoir of his or her own work? Abstracts of oral presentations? Textbooks? Monographs? Book reviews? Obituaries? Then there is the problem of posthumous publications. Probably most would include papers in the pipeline when the astronomer dies, but what about the case where the coauthor finally publishes the paper eight years after the death of the person of interest? I eventually decided to make two lists, one which would include most of the above, and one restricted to papers that make contributions to physical science. Note that I do not say "refereed," as that presents its own problems, especially when applied to periods before the twentieth century.

115.03 – **Perigean Spring Tides and Apogean Neap Tides in History**

Donald W. Olson[1]

[1]*Texas State Univ..*
10:30 AM - 10:45 AM

On January 4, 1912 - almost exactly 100 years ago - both a full Moon and a lunar perigee occurred, with these two events separated by only a few minutes of time and with the Earth near perihelion. The resulting lunar distance (356,375 km) on that date stands as the closest approach of the Moon to the Earth in an interval of more than 1400 years. The centennial of this extreme lunar perigee is an appropriate time to consider the effect of lunar distance on the range of ocean tides.

At most ocean ports, spring tides of increased range occur near new and full Moon. If a lunar perigee falls near new or full Moon, then perigean spring tides of even greater range are possible. Conversely, if a lunar apogee falls near first quarter or last quarter Moon, then apogean neap tides of unusually reduced range can occur.

Examples of perigean spring tides include a near-coincidence of lunar perigee and new Moon in December 1340 that may be related to a plot device in Chaucer's "The Franklin's Tale," a Canterbury tale that describes an extreme high tide covering the rocks on the coast of Brittany in "the cold and frosty season of December." Another example, the disaster known as the Bristol Channel Flood, occurred shortly after a lunar perigee and new Moon in January 1607. A German U-boat employed an exceptionally high perigean spring tide shortly after the new Moon of October 1939 to enter Scapa Flow by an unexpected route and sink the HMS *Royal Oak*. An apogean neap tide prevailed during the amphibious assault of the U. S. Marines at Tarawa in November 1943, making the eventual victory more costly because the landing craft were unable to reach the island and instead grounded on the surrounding reef.

115.04 – **Use of Monte Carlo Methods for Evaluating Probability of False Positives in Archaeoastronomy Alignments**

Anthony B. Hull[1], C. Ambruster[2], E. Jewell[3]

[1]*University of New Mexico,* [2]*Villanova University,* [3]*University of Phoenix.*
10:45 AM - 11:00 AM

Simple Monte Carlo simulations can assist both the cultural astronomy researcher while the Research Design is developed and the eventual evaluators of research products. Following the method we describe allows assessment of the probability for there to be false positives associated with a site. Even seemingly evocative alignments may be meaningless, depending on the site characteristics and the number of degrees of freedom the researcher allows. In many cases, an observer may have to limit comments to "it is nice and it might be culturally meaningful, rather than saying "it is impressive so it must mean something". We describe a basic language with an associated set of

attributes to be cataloged. These can be used to set up simple Monte Carlo simulations for a site. Without collaborating cultural evidence, or trends with similar attributes (for example a number of sites showing the same anticipatory date), the Monte Carlo simulation can be used as a filter to establish the likeliness that the observed alignment phenomena is the result of random factors. Such analysis may temper any eagerness to prematurely attribute cultural meaning to an observation. For the most complete description of an archaeological site, we urge researchers to capture the site attributes in a manner which permits statistical analysis. We also encourage cultural astronomers to record that which does not work, and that which may seem to align, but has no discernable meaning. Properly reporting situational information as tenets of the research design will reduce the subjective nature of archaeoastronomical interpretation. Examples from field work will be discussed.

115.05 – **Discovery that the Magnitudes in the Ancient Star Catalogs of Ptolemy, Al-Sufi, and Tycho Were All Corrected for Atmospheric Extinction**

Bradley E. Schaefer[1]

[1]*Louisiana State Univ..*

11:00 AM - 11:15 AM

The three ancient star catalogs of Ptolemy (c. 127, Alexandria Egypt), Al Sufi (c. 961, Isfahan Iran), and Tycho Brahe (c. 1600, Hven now in Sweden) all record independent measures of the visual magnitudes of close to a thousand stars over their entire visible sky. For stars culminating 60° from zenith to the south (around -29° declination for Alexandria), they should appear roughly a quarter or a third of a magnitude fainter than those at zenith, and this is easily detected with the many stars near this declination band, despite the quantization of the reported magnitudes to roughly one third of a magnitude. For stars near the southern limit, the dimming should be 1-2 mag. To seek this effect, I use stars culminating near zenith to set up a correspondence between the reported magnitudes and modern V magnitudes, compare the modern equivalent magnitude to the star's real magnitude, and looked to see the dimming as the southern horizon is approached. Surprisingly, no dimming towards the south is viewed in any of the three ancient star catalogs. A formal fit to the effective extinction coefficient for each catalog is +0.01+-0.01, +0.05+-0.01, and +0.01+-0.01 mag/airmass respectively. That is, the reported magnitudes have already been corrected for extinction. This new result is surprising because no astronomer or historian has previously reported the effect. This is also surprising because no written source before 1729 even mentions the existence of the phenomenon of extinction (although the effect is easily recognized by any studious visual observer), so the expectation would be that the pre-telescopic astronomers were not aware of the phenomenon, not interested, or not able to do the corrections. Nevertheless, this discovery that the ancient catalogers all corrected for extinction opens new horizons in 'archaeophotometry' and new recognition for the ability of pre-telescopic observers.

115.06 – **Where Did John Goodricke Make His Observations? New Evidence**

Linda French[1]

[1]*Illinois Wesleyan University.*

11:15 AM - 11:30 AM

Much effort has gone into determining the location from which John Goodricke (1764-1786) made most of his observations. Sidney Melmore (1949) made the first determination, and he decided that the most likely location was a south-facing window of Treasurer's House, a large property facing onto York Minster, the largest Gothic cathedral in Northern Europe. Melmore made his determination by looking at the stars observed by Goodricke in his "Journal of the Going of My Clock," from which it is possible to infer the direction in which Goodricke was looking. There are problems with Melmore's identification, however: the wing of Treasurer's House he identified was, at that time, occupied by several spinster daughters of a wealthy landowner. The presence of these ladies makes it highly unlikely that a teenaged boy would have been allowed in to make astronomical observations at night. An alternative solution is presented.

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116 – Early Science Results from the SOFIA Observatory

Special Session – Ballroom E – Monday, January 9, 2012, 10:00 AM - 11:30 AM

The Stratospheric Observatory for Infrared Astronomy (SOFIA), a jointproject between the United States National Aeronautics and SpaceAdministration (NASA) and the German Aerospace Center (DLR), is a2.5-meter infrared airborne telescope in a Boeing 747-SP that achievedfirst light on May 26, 2010 and began science flights on December 1, 2010. Operating in the stratosphere at altitudes as high as 45,000 feet, SOFIAcan conduct photometric, spectroscopic, and imaging observations atwavelengths from 0.3 microns to 1.6 millimeters with an averagetransmission of greater than 80 percent. SOFIA is staged out of the NASADryden Flight Research Center aircraft operations facility at Palmdale, CAand the SOFIA Science Mission Operations Center is located at NASA AmesResearch Center, Moffett Field, CA.

SOFIA's access to regions of the atmosphere that are opaque from theground, its rapid and global deployment capability, and its ability toincorporate new and updated instruments, guarantee that the observatorywill play an important role studying a variety of key astrophysicalproblems. SOFIA's first-generation instrument complement includes highspeed photometers, broadband imagers, moderate-resolution spectrographscapable of resolving broad features due to dust and large molecules, andhigh-resolution spectrometers suitable for kinematic studies of molecularand atomic gas lines at km/s resolution. About 100 eight to ten hourflights per year are expected by 2014, and the observatory will operateuntil the mid 2030's.

116.01 – **SOFIA Program Status**

Pamela M. Marcum[1]

[1]*Texas Christian Univ..*

10:00 AM - 10:10 AM

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is an airborne infrared observatory with a 2.5-meter telescope, with science instrumentation that spans wavelengths from optical through the far infrared, with imaging and spectroscopy capabilities. A brief overview of the SOFIA program will be provided, including recent progress and milestones.

116.02 – **SOFIA Overview and science capabilities for Cycle 1**

Erick T. Young[1]

[1]*SOFIA/USRA.*

10:11 AM - 10:21 AM

SOFIA, the Stratospheric Observatory for Infrared Astronomy, is a joint project of NASA and the German Aerospace Center. It is a highly modified Boeing 747SP aircraft housing a 2.7-meter diameter telescope. Operating at altitudes as high as 14 km (45,000 ft.), SOFIA makes possible observations in otherwise obscured parts of the infrared. SOFIA will be offering approximately 200 hours of openly competed observing time to the world-wide astronomical community in an upcoming Call for Proposals. Four scientific instruments will be offered: FLITECAM, a near infrared camera and spectrometer; FORCAST, a mid-infrared camera; GREAT, a submillimeter heterodyne spectrometer; and HIPO, an visible light occultation photometer. This talk describes the call for proposals and the offered capabilities.

116.03 – **First Science Results from SOFIA/FORCAST: Properties of Protostars and Circumstellar Disks in OMC-2**

Joseph D. Adams[1], T. L. Herter[1], M. Osorio[2], S. T. Megeath[3], L. D. Keller[4], J. M. De Buizer[5]

[1]*Cornell Univ.,* [2]*IAA, Spain,* [3]*U. Toledo,* [4]*Ithaca Coll.,* [5]*SOFIA/USRA.*

10:22 AM - 10:32 AM

We present observations of eight intermediate luminosity protostars and circumstellar disks in OMC-2 detected by SOFIA/FORCAST during the SOFIA short science phase. We combined the SOFIA/FORCAST observations with observations from the Spitzer Orion Molecular Cloud Survey, The Herschel Orion Protostar Survey, and ground-based data published in the literature in order to construct a spectral energy distribution for each object from the near-infrared to the submillimeter. The observed sources can be modeled as protostars with infalling envelopes heated by internal sources or as pre-main sequence stars surrounded by dusty disks. The reddest, most deeply embedded source (FIR 4) can be modeled as a 60 Lsun, Class 0 protostar with a predicted infall rate of 3E-4 Msun per year. One of the detected sources with an unusual SED may be a disk which is externally heated by other luminous sources in the Orion region.

116.04 – **GREAT Highlights from the SOFIA Early Science Flights**

Hans Zinnecker[1], R. Gusten[2], GREAT Team

[1]*NASA Ames Research Center,* [2]*Max Plack Institute for Radio Astronomy, Germany.*

10:33 AM - 10:43 AM

Since its first light on April 01, the German REceiver for Astronomy at TeraHertz Frequencies (GREAT) has flown more than a dozen SOFIA science flights both for US and German proposals. The spectrometer was operated routinely in its low frequency configurations, for sky frequencies between 1.25 and 1.5 THz (L1 channel) and

1.81-1.91 THz (L2 channel). During a GREAT engineering flight, the 2.5 THz OH ground-state transition was successfully observed. We will summarize the science opportunities with GREAT and present highlights from these Early Science flights.

116.05 – **SOFIA Observations of Orion with FORCAST**

James M. De Buizer[1], J. D. Adams[2], E. E. Becklin[3], T. L. Herter[2], M. R. Morris[4], R. Y. Shuping[5], W. D. Vacca[6], H. Zinnecker[7]

[1]SOFIA/USRA, [2]Cornell University, [3]UCLA/SOFIA-USRA, [4]UCLA, [5]Space Science Inst./SOFIA-USRA, [6]SOFIA-USRA, [7]SOFIA-DLR.

10:44 AM - 10:54 AM

The inner three square arcminute area of the Orion nebula, centered on the Trapezium and including the BN/KL region, was observed as a part of Early Science observations with SOFIA. Using the 5-40 micron camera FORCAST, we imaged this region at 6.6, 7.7, 19.7, 31.5, and 37.1 microns. These observations provide the highest resolution images ever obtained for these latter two wavelengths with a resolution of FWHM~3 arcseconds. Here we present data on the whole area, concentrating on the results obtained for the BN/KL region, where the mid-infrared intensities and dust color temperature distribution help determine which sources are internally and externally heated. In particular, our observations show that the BN object itself is not a dominant luminosity source at wavelengths >30 microns, and that the brightest source at our longest wavelengths is IRc4, which appears to be self-luminous.

116.06 – **First Stellar Occultation Observation with SOFIA**

Edward W. Dunham[1], T. Bida[1], A. Bosh[2], P. Collins[1], S. Levine[1], M. Person[2], E. Pfueller[3], H. Roeser[4], B. Taylor[5], M. Wiedemann[3], J. Wolf[3], C. Zuluaga[2]

[1]Lowell Observatory, [2]MIT, [3]Deutches SOFIA Institut, Germany, [4]Institut fuer Raumfahrtsysteme, Universitaet Stuttgart, Germany, [5]Boston University.

10:55 AM - 11:05 AM

We successfully observed the 2011 June 23 UT stellar occultation by Pluto with the High-speed Imaging Photometer for Occultations (HIPO) instrument from Lowell Observatory and the Fast Diagnostic Camera (FDC) from the Deutches SOFIA Institut (DSI) mounted on the SOFIA telescope. A major prediction astrometry effort focused at MIT combined with the willingness of the SOFIA project to entertain the idea of an in-flight change to the flight plan allowed us to target the center of the occultation shadow. This was accomplished by means of an in-flight prediction update by satellite telephone and a real-time onboard flight plan modification to accommodate the prediction update. We obtained excellent results with both channels of HIPO and the FDC with each light curve showing a small, extended brightening while the star was occulted. We will discuss analysis results as well as SOFIA's considerable potential for future occultation work.

We thank the SOFIA program for its willingness to attempt this challenging observation at such an early stage of SOFIA science operations. Lowell's SOFIA work was supported by a grant from USRA, MIT's prediction work was supported by the NASA Planetary Astronomy Program and the National Science Foundation, and the FDC work was supported by the DSI. We thank the US Naval Observatory Flagstaff Station for allowing us to use their facilities to obtain our prediction astrometry observations.

116.07 – **SOFIA FORCAST Images of the Bipolar Planetary Nebula M2-9**

Michael W. Werner[1], J. Davis[2], R. Sahai[1], M. Morris[3], L. Keller[4], T. Herter[5]

[1]JPL, [2]Caltech, [3]UCLA, [4]Ithaca College, [5]Cornell University.

11:06 AM - 11:16 AM

As part of a SOFIA Basic Science program to study compact planetary nebulae, we have obtained images of the bipolar nebula M2-9, using the FORCAST bands at 6.6, 11.1, 19.7, 24.2, 33.6, and 37.1um. All images show a very bright point like central condensation associated with the exciting star of the nebula and the surrounding circumstellar dust. At the four longest wavelengths, the two bipolar lobes are seen in the images, extending some 20 arcsec from the central star. The integrated signal from each of the lobes may be visible at the two shorter wavelengths as well. The intensity and spectrum of the infrared radiation from the lobes is consistent with thermal emission from grains entrained in the bipolar outflow, and seen at visible wavelengths in scattered starlight. We compare the structure of the lobes as seen from SOFIA with that seen in Hubble images and report the results of attempting to fit the lobe profiles with emission from an outflow cavity with limb-brightened edges.

Jessica Davis was the Charles and Valerie Elachi SURF Fellow at JPL during the summer of 2011. We appreciate the support of Jim DeBuizer and others at the Sofia Science Center. Portions of this research were carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

116.08 – **Search for Interstellar Mercapto Radicals (SH) with SOFIA**

David A. Neufeld[1]

[1]Johns Hopkins University.

11:17 AM - 11:27 AM

The first results of a search for interstellar SH - obtained using the GREAT instrument on SOFIA - will be reported. The mercapto radical - never previously observed in the ISM - is predicted to trace warm regions where the interstellar gas is heated by shocks or the dissipation of turbulence

117 – Making the Most of Your Oral Presentations

Special Session – Room 18A – Monday, January 9, 2012, 10:00 AM - 11:30 AM

Strong oral presentation skills are a key to success for engineers, scientists, and other professionals, yet many speakers are at a loss to tackle the task. Systematic as they otherwise can be in their work, they go at it intuitively, sometimes haphazardly, with much good will but seldom good results. This lecture proposes a systematic way to prepare and deliver presentations and covers structure, slides, and stage fright among other topics.

118 – A (Re)introduction to the Milky Way

Invited Session – Ballroom D – Monday, January 9, 2012, 11:40 AM - 12:30 PM

118.01 – **A (Re)introduction to the Milky Way**

Robert A. Benjamin[1]

[1]Univ. of Wisconsin,Whitewater.

11:40 AM - 12:30 PM

If your picture of the Milky Way is that it consists of a bulge, disk, and halo, you might want to attend this talk. I will review the many recent advances in understanding the global structure of our Galaxy, with a principal emphasis on the disk and inner galaxy. Radio parallaxes to maser sources, extinction distances to dark clouds, and large-scale near and mid-infrared mapping of red clump giants now allow us to map out different components (star formation, gas, and old stars) of the Galaxy without the serious issues that plagued earlier efforts. The Milky Way contains two (possibly three) bar-like components with a complex morphology. Intense star formation with several massive stellar clusters and kiloparsec-scale superbubbles are seen at near end of the bar, while the situation at the far end of the bar is less clear. Three new sections of gaseous spiral arms have been discovered since 2000; their estimated locations hint that the Milky Way may be quite symmetric. In the outer reaches of the Galaxy, the stellar disk warps in a qualitatively similar way to the HI disk, and possibly truncates. After reviewing these advance, I will summarize what we don't yet know about the Galaxy. After 60 years of effort, I'd say we're about 50% done.

119 – JWST Town Hall

Town Hall – Ballroom G – Monday, January 9, 2012, 12:45 PM - 1:45 PM

The James Webb Space Telescope will be the most powerful telescope that astronomers have ever constructed, and is essential to answering the top science questions outlined in the recent Astronomy 2010 - 2020 Decadal Survey. In 2011, the observatory reached several milestones including completion of key optical components. This town hall will feature presentations by Eric Smith (NASA HQ), Matt Greenhouse (NASA GSFC), and David Charbonneau (CfA). There will be time left for community comments and questions.

120 – HAD Business Meeting

Town Hall – Room 12A – Monday, January 9, 2012, 12:45 PM - 1:45 PM

Annual business meeting of the Historical Astronomy Division.

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121 – NSF Town Hall

Town Hall – Ballroom E – Monday, January 9, 2012, 12:45 PM - 1:45 PM

NSF staff from the Division of Astronomical Sciences will present current news on budget, programs, progress on the Astro2010 decadal survey recommendations, and the status of the Division's portfolio review.

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122 – Cutting-Edge Dynamics: From Planetary Rings to Galaxies

Special Session – Room 16B – Monday, January 9, 2012, 2:00 PM - 3:30 PM

The past decade has seen great advances in different fields of dynamical astronomy. Ground- and space-based telescopes have detected several hundred extrasolar planets and more than one thousand planetary candidates, each with its own unique dynamical and physical characteristics. Fascinating data from missions to the inner and outer parts of the solar system have answered some and raised new questions about planetary interiors, rings, and satellites. Increases in the precision of tracking spacecrafts have opened new avenues into fundamental physics. High precision astrometry with HIPPARCOS, the FGS instrument on HST, and VLBI has impacted galaxy dynamics, and HST observations of galactic nuclei have strengthened the evidence for SMBHs. In this special session we present some of the latest and best research on the above-mentioned topics that were presented in the 2011 annual meeting of the Division on Dynamical Astronomy. DDA plays and continues to play an important role in the advancement of all aspects of dynamical astronomy, including celestial mechanics, solar system dynamics, stellar dynamics, the dynamics of the interstellar medium, and galactic dynamics. We have chosen a diverse set of topics from the major achievements reported at the last DDA meeting. The talks in this session will provide insight into future trends and methodologies in the field of dynamical astronomy from the dynamics of galaxies to planet formation and solar system bodies.

122.01 – **New Developments in Spiral Structure Theory**

Jerry Sellwood[1]

[1]*Rutgers Univ.*.

2:00 PM - 2:15 PM

Over 150 years after their discovery, astronomers still lack a complete theory for the origin of the beautiful spiral patterns in disk galaxies. I will review the various ideas that have been proposed, present a mechanism for a cycle of recurrent instabilities, and describe some recent observational data that appear to support it.

122.02 – **Asteroid Impact Hazard Assessment Over Long Time Intervals**

Steven R. Chesley[1]

[1]*Jet Propulsion Laboratory, California Institute of Technology.*

2:17 PM - 2:32 PM

Asteroid impact hazard monitoring has so far focused primarily on warning of potential impact threats within the next century. This 100-year search horizon is generally appropriate because impact mitigation efforts over longer time horizons are often precluded due to low impact probabilities associated with long-term predictions. Moreover, searching farther into the future for potential impacts is problematic, first because the fractal nature of keyholes means that most recent asteroid discoveries harbor a cascade of many very low probability events beyond several decades in the future, leading to a significant increase in computational cost for longer searches. But more importantly, the standard theories used in the current impact monitoring systems become inadequate for longer search intervals.

Well-observed asteroids with high-precision orbits represent a different class of object for impact monitoring. In these cases the future trajectory may be well known for a long period, a century or more, until the object has a close planetary encounter that scatters the range of possible trajectories, thereby injecting a large amount of uncertainty. At that future point the problem can become similar to that of a newly discovered asteroid, with a wide range of future trajectories. Nongravitational accelerations, namely the Yarkovsky Effect, can also become an important consideration. Assessing the uncertainty due to the Yarkovsky effect can be difficult, especially when the spin state of the object is not known, and yet reasonable assumptions can be followed to estimate the dispersion due to this effect. In many high precision cases the Yarkovsky spreading remains small relative to the dispersions due to planetary encounters and so it can be neglected. But when the uncertainty due to the Yarkovsky Effect is large enough to significantly alter the circumstances of a planetary encounter it must be incorporated into the impact assessment.

122.03 – **Constraining the Size of the Protosolar Nebula**

Katherine A. Kretke[1]

[1]*Southwest Research Institute.*

2:34 PM - 2:49 PM

Observations indicate that the gaseous circumstellar disks around young stars vary significantly in size, ranging from tens to thousands of AU. Models of planet formation depend critically upon the properties of these primordial disks, yet in general it is impossible to connect an existing planetary system with a observed disk. We present a method to constrain the size of our own protosolar nebula using the properties of small body reservoirs in the solar system. After Jupiter formed, it scattered a significant number of remnant planetesimals into highly eccentric orbits. If there had been a massive, extended protoplanetary disk at that time, then the disk would have excited Kozai oscillations in some of the scattered objects, driving them into high-inclination, low-eccentricity orbits. The dissipation of the gaseous disk would strand a population of objects in these high-inclination orbits; orbits that are stable on Gyr time scales. Using limits derived from the non-detection of these high inclination objects in the Deep Ecliptic Sky Survey, we can constrain the size of our gaseous protoplanetary disk at the time of Jupiter's formation to within 50 AU.

122.04 – **Confirming the Lense-Thirring Orbital Precession with Satellite Laser Ranging to the LAGEOS Satellites and GRACE Gravity Models**

John C. Ries[1], R. J. Eanes[1]

[1]*Univ. of Texas, Austin.*

2:51 PM - 3:08 PM

The theory of General Relativity predicts several non-Newtonian effects that have been confirmed by experiment, to considerable accuracy in some cases, but directly confirming the ³frame dragging² effect has been challenging. One manifestation of this effect is the Lense-Thirring precession of a satellite's orbital plane due to the Earth's rotation. While the signal is large enough to be easily observed with satellite laser ranging, the Lense-Thirring measurement uncertainty is limited by the knowledge of the even zonal harmonics of the Earth's gravity field that produce similar but much larger Newtonian secular orbit precessions. In the late 1980's, it was proposed to launch the LAGEOS-3 satellite matching LAGEOS-1, except that the orbit inclination would be exactly supplementary to LAGEOS-1. This would have allowed the cancellation of the equal but opposite orbit precession due to the Earth's gravity field to reveal the Lense-Thirring precession. At about the same time, LAGEOS-2 was being prepared for launch, but the orbit selected for that satellite was not sufficiently close to the proposed LAGEOS-3 orbit specifications to support an accurate Lense-Thirring experiment with the available gravity models. However, the problem of the uncertainty in the knowledge of the Earth's gravity field has been largely overcome with the dramatically improved models resulting from the joint NASA-DLR Gravity Recovery and Climate Experiment (GRACE) mission. Using laser ranging to LAGEOS-1 and LAGEOS-2, it is now possible to confirm the General Relativity prediction of the Lense-Thirring precession with an uncertainty better than 15%.

This research was supported by NASA Contract NNG06DA07C.

122.05 – **Ring Dynamics at Saturn: Wakes, Resonances, Warps and Orbital Migration**

Philip D. Nicholson[1], M. M. Hedman[1], M. S. Tiscareno[1], J. A. Burns[1], R. G. French[2], R. G. French[2], E. A. Marouf[3], J. E. Colwell[4]

[1]*Cornell Univ.*, [2]*Wellesley College*, [3]*San Jose State University*, [4]*University of Central Florida.*

3:10 PM - 3:25 PM

In addition to their incomparable beauty in a small telescope, the rings of Saturn have long provided astronomers with a nearby laboratory for developing and testing theories of disk dynamics. After seven years of successful operations, the Cassini orbiter has greatly increased our knowledge of this system, and revealed many new and unexpected

phenomena. Ring thicknesses of as little as 5-10 meters are inferred from particle velocity dispersions and from the ubiquitous `self-gravity wakes'. The latter are close cousins of the trailing structures seen in simulations of self-gravitating stellar disks in the 1980s. Two of the 15 or so narrow gaps in the rings are maintained by km-size embedded moonlets; the others remain unexplained though several have edges defined by Lindblad resonances with larger, external satellites. Many gap and ringlet edges are noncircular, exhibiting a surprisingly wide range of perturbations which seem to reflect multiple `normal modes' excited within the rings. Images taken near the Saturnian equinox in mid-2009 under conditions of grazing solar illumination reveal a spiral-shaped warp which extends all the way across the C and D rings. Models of this structure strongly suggest that it is due to an impact on the rings of a cloud of interplanetary debris in September 1983, perhaps due to a disrupted comet like Shoemaker-Levy 9. Although even Cassini is unable to image individual ring particles, the highest resolution images of the A ring show intriguing structures known as `propellers' which appear to be the gravitational signature of large embedded objects, perhaps 100 m in size. Long-term tracking of the largest propellers shows clear evidence for non-keplerian motion, possibly akin to the orbital migration predicted for protoplanets embedded in circumstellar disks.

123 – Extra-Galactic Star Clusters

Oral Session – Room 18D – Monday, January 9, 2012, 2:00 PM - 3:30 PM

123.01 – **SHUCS: the Snapshot Hubble U-band Cluster Survey**

Iraklis Konstantopoulos[1], SHUCS collaboration

[1]*Penn State University.*
2:00 PM - 2:10 PM

Star clusters represent a step in the star formation hierarchy above individual stars. As such, they maintain a link to the overall star formation in any galaxy, while their brightness turns them into beacons of star formation in systems out to ~100 Mpc. The study of extra-galactic star clusters and their populations has undergone a revival since the launch of HST. However, their use as direct tracers of star formation depends on understanding fundamental laws that regulate the fraction of stars that form in clusters, as well as those that govern the destruction of star clusters.

The Snapshot Hubble U-band Cluster Survey (SHUCS) is designed to take a few steps in that direction. By completing the UBVI baseline for galaxies with existing archival BVI coverage, we will derive the ages, masses and luminosities of thousands of clusters in 22 galaxies. This way we will be able to rule out theories and empirical scenarios regarding the formation and destruction of star clusters, and the role of environment in these processes.

This talk will present a description of the survey and its many goals, and go through some first results.

123.02D – **High-Redshift Cluster Formation via Galaxy Outflows and its Relation to Halo Globular Clusters**

William J. Gray[1], E. Scannapieco[1]

[1]*Arizona State University.*
2:10 PM - 2:30 PM

The early Universe hosted a large population of small dark matter 'minihalos' that were too small to form stars on their own. Thus they existed as static objects around larger starburst galaxies until they were acted upon by some outside influence. Outflows, which have been observed around a variety of galaxies, can provide this influence in such a way as to collapse, rather than disperse the minihalo gas.

I have implemented a primordial non-equilibrium chemistry package with associated cooling rates and a model for turbulence that captures mixing processes in the AMR code FLASH. Using a simple model for the minihalo and outflow, I show that, over a wide range of model parameters, the outcome from this interaction is one or more small dense clusters of enriched, star-forming gas. These clusters will be observable with the next generation of telescopes, and they have properties remarkably like those of present-day halo globular clusters.

123.03D – **The Effects Of Tides, Rotation, And Pressure Anisotropy On The Dynamics Of Globular Clusters**

Anna L. Varri[1]

[1]*Universita' degli Studi di Milano, Italy.*
2:30 PM - 2:50 PM

To fully understand the internal dynamics of globular clusters, a number of important physical ingredients, in particular the three-dimensional effects of external tides, internal rotation, and anisotropy in velocity space, should be added to the traditional paradigm that relies on spherical non-rotating models of quasi-relaxed stellar systems. In fact, the great progress recently made in the acquisition of detailed photometric and kinematic information on the structure of globular clusters calls for a renewed effort in theoretical modeling.

Driven by these motivations, I have constructed a family of triaxial models that incorporate in a self-consistent way the tidal effects of the host galaxy. I have also studied the effects of the presence of internal rotation, by constructing two new families of axisymmetric equilibria, flattened by either solid-body or differential rotation. The basic properties of the models have been derived analytically. I have also performed an extensive survey of N-body simulations designed to investigate the dynamical stability and the long-term evolution of the rotating models. Configurations in the moderate rotation regime, relevant to globular clusters, are found to be dynamically stable; in turn, a new dynamical instability is observed in models characterized by strong rotation and high degree of shear, in striking analogy with recent stability analyses of differentially rotating fluids. Curiously, there exists an intermediate regime in which systems exhibit a central toroidal structure and are dynamically stable.

Within this primarily analytical framework, several theoretical and observational issues can be addressed. In particular, I have considered the morphological effects induced by different tidal environments, the dynamical interplay between angular momentum transport and two-body relaxation processes, and the physical origin of the observed deviations from spherical symmetry, also by means of a comparison between analytical models and observational data for selected Galactic globular clusters.

123.04D – **The Formation and Evolution of M33 as Revealed by its Star Clusters**

Izaskun San Roman[1]

[1]*University of Florida.*
2:50 PM - 3:10 PM

Star clusters provide a unique and powerful tool for studying the star formation histories of galaxies. In particular, the ages and metallicities of star clusters bear the imprint of the galaxy formation process. M33 is the only nearby late-type spiral galaxy and provides a notable connection between the cluster populations of earlier-type spirals, and the numerous nearby later-type dwarf galaxies. I have carried out a comprehensive study of the M33 star cluster system, including deep photometry as well as high signal-to-noise spectroscopy. I have undertaken a photometric survey for extended sources in a 1deg x 1deg area centered on M33 using the MegaCam camera on the 3.6m Canada-France-Hawaii Telescope. This study mitigates the incompleteness present in the current catalogs of star clusters in M33, especially in the outskirts of this galaxy. I will discuss here the photometric properties of the sample, including color-color diagrams of 599 new candidate stellar clusters, and 204 confirmed clusters. Analysis of the radial density distribution suggests that the cluster system of M33 has suffered from significant depletion, possibly due to interactions with M31. Additionally, I will present the morphological properties of 161 star clusters in M33 using ACS/HST images. I found that the position angles of the M33 clusters show a bimodality with a strong peak perpendicular to the position angle of the galaxy. This evidence supports tidal forces as the reason for cluster elongation. Finally, I will present high-precision velocity measures of a variety of M33 star clusters, based on observations from the 10.4m Gran Telescopio Canarias and 3.6m William Herschel Telescope.

123.05D – **The Resolved Stellar Population in 50 Regions of M83 from HST/WFC3 Observations**

Hwihyun Kim[1]

[1]*Arizona State University.*
3:10 PM - 3:30 PM

We present a multi-wavelength photometric study of ~15,000 resolved stars in the nearby spiral galaxy M83 (D=4.61Mpc) based on Hubble Space Telescope/Wide Field Camera 3 (HST/WFC3) observations using four filters: F336W, F438W, F555W, and F814W. We select 50 regions in the spiral arm and inter-arm areas of M83, and determine the age distribution of the luminous stellar population in each region by combining its color-magnitude diagram (CMD) and color-color diagram with the stellar isochrones. To improve stellar age estimates from isochrone fitting on CMDs, we correct for extinction towards each individual star by comparing its colors with predictions from stellar isochrones. We compare the resulting ages of the 50 regions with those determined from several independent methods, including the number ratio of red-to-blue supergiants, the morphological appearance of the regions, and surface brightness fluctuations, and find fairly good agreement between these methods. We find that young stars are much more likely to be found in concentrated aggregates, while older stars are more dispersed. We also compare the typical ages of stars with those of the clusters within the 50 regions. These results are both consistent with a picture where stars form in star clusters and then disperse on short timescales to form the field population. The locations of Wolf-Rayet star candidates are found to correlate with the positions of many of the youngest regions, providing additional support for our ability to accurately estimate ages.

This work 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.

124 – Increasing Diversity in Your Department

Special Session – Room 12B – Monday, January 9, 2012, 2:00 PM - 3:30 PM

Diversity is becoming increasingly important as a component of a successful department. As examples, the rankings of graduate programs by the National Academies highlight diversity as a criterion and diversity is an important component of the broader impact statements required by NSF proposals. This special session will present hiring policies and practices that have been proven to be effective in increasing both the diversity and the excellence of science departments around the country. We will recommend steps that departments can take to recruit and retain women, LGBT people, and minorities; discuss what factors contribute to a friendly departmental climate; and demonstrate how to create a diverse department while enhancing academic quality. We invite members of the AAS community to attend this session to both share their own ideas and learn new ones.

124.01 – **Best Practices in Hiring: Addressing Unconscious Bias**

Caroline E. Simpson[1]

[1]*Florida International Univ.*.

2:00 PM - 2:20 PM

Research has shown that implementing certain hiring practices will increase diversity in the workplace while enhancing academic quality. All of these practices rely on addressing

the issue of 'unconscious bias.' A brief overview of unconscious bias--what it is, how it works, and simple measures to counter it--will be presented. Successful strategies, actions, and recommendations for implementing best recruiting and hiring practices, which have been proven to enhance academic excellence by ensuring a deep and diverse applicant pool, will also be presented.

124.02 – **Tools for Recruiting a Diverse Applicant Pool**

Andrew A. West[1]

[1]*Boston University.*

2:20 PM - 2:40 PM

Diversity is important to the productivity, perspective and general health of an academic department. Despite its importance, only a few percent of faculty members (and only a slightly higher percentage of graduate students) in astronomy are underrepresented minorities. Many departments claim that this dearth is due to the small (or non-existent) number of underrepresented applicants. While problems with the academic pipeline do limit the size of the pool, many departments are unaware of a variety of tactics that can be used to maximize the number of underrepresented applicants to both graduate school and faculty positions. I will present a number of strategies for increasing the diversity of both graduate student and faculty applicants to academic programs. My recommendations come from personal experience as well as discussions with numerous colleagues at several institutions.

124.03 – **Recruitment and Retention of LGBTIQ Astronomers**

William Van Dyke Dixon[1]

[1]*STSci.*

2:40 PM - 3:00 PM

While lesbian, gay, bisexual, transgender, intersex, or questioning (LGBTIQ) astronomers face many of the same workplace challenges as women and racial/ethnic minorities, from implicit bias to overt discrimination, other challenges are unique to this group. An obvious example is the absence at many institutions of health insurance and other benefits for the same-sex domestic partners of their employees. More subtle is the psychological toll paid by LGBTIQ astronomers who remain "in the closet," self-censoring every statement about their personal lives. Paradoxically, the culture of the physical sciences, in which sexuality, gender identity, and gender expression are considered irrelevant, can discourage their discussion, further isolating LGBTIQ researchers. Addressing these challenges is not just a matter of fairness; it is an essential tool in the recruitment and retention of the brightest researchers and in assuring their productivity. We will discuss these issues and what individuals and departments can to make their institutions more welcoming to their LGBTIQ colleagues.

124.04 – **Getting to Family-Friendly in Your Department**

Catherine A. Pilachowski[1]

[1]*Indiana University.*

3:00 PM - 3:20 PM

These days, most academic and research institutions recognize the importance of a family-friendly workplace, and have implemented at least some policies to support a sustainable work-life balance: family and medical leave, parental leave, stopping or extending tenure clocks, modified duty policies, breast feeding policies and lactation rooms, partner hiring programs, childcare programs, eldercare programs, emergency and sick child care programs, dependent care travel funds, etc. But while institutions may offer a menu of policies and free or low-cost services to support families, what's happening in your department? Achieving a supportive workplace culture requires that we dispel some of the myths associated with family-friendly policies, and establish that family-friendly policies not only benefit all employees, but also help the institution be more successful.

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125 – Exoplanets: New Surveys

Oral Session – Ballroom F – Monday, January 9, 2012, 2:00 PM - 3:30 PM

125.01 – **The McDonald Observatory Exoplanet Program**

Michael Endl[1], W. D. Cochran[1], P. J. MacQueen[1], P. Robertson[2], E. J. Brugamyer[2], C. Caldwell[2]

[1]*McDonald Observatory / University of Texas at Austin,* [2]*University of Texas at Austin*.

2:00 PM - 2:10 PM

We present a review of the McDonald Observatory Exoplanet Program at the Harlan J. Smith 2.7 m Telescope and the Hobby-Eberly Telescope. Besides planet confirmation and validation for NASA's Kepler mission we also carry out a precise Doppler survey of 400 solar-type stars and 100 M dwarfs. We will summarize current results, present several new exoplanet discoveries and discuss future prospects in observing strategies and instrumentation.

125.02D – **Searching For Planets Around M Dwarfs Using the Radial Velocity Technique**

Ji Wang[1], J. Ge[1], X. Wan[1]

[1]*University of Florida.*

2:10 PM - 2:30 PM

M dwarfs account for 70% of stars in the solar neighborhood, but less than 5% of the known exoplanets orbit these cool, red stars. Despite the overwhelming success of the radial-velocity method in detecting more than 500 planets to date, not a single planet has been found to orbit a late-type M dwarf.

I conducted simulations to investigate the photon-limited performance of RV instruments using two methods, the dispersed fixed-delay interferometer (DFDI) method and the traditional echelle method. I found that the instrument using the DFDI method is more advantageous in the multi-object survey at a low-median spectral resolution.

I used the EXPERT spectrograph (R=27,000) at the 2.1 m telescope on Kitt Peak to demonstrate the feasibility of telluric-line modeling with a telluric standard star. The featureless spectrum of a fast-rotating hot star is observed nearby the science star in order to obtain a telluric-line absorption spectrum, which is later used to remove the telluric-line contamination from the spectrum of the science star.

A signicant innovation of my PhD work is the development of a portable inexpensive wavelength calibration source with the potential of reaching better than 10 cm/s precision. I have compared this source to an Iodine cell and a Th-Ar emission lamp in the optical wavelength. The results show that different sources track each other to within 10 m/s. The number is expected to be decreased once the radial-velocity code is improved. The proposed wavelength calibration source provides an alternative to the expensive laser comb technology, which is the only technique that offers a comparable precision in the I band (0.7-0.9 micron).

125.03D – **New Detections of Planet-Mass Companions to K-Giants by the Penn State - Torun Planet Search**

Sara Gettel[1], A. Wolszczan[1], A. Niedzielski[2], G. Nowak[2], M. Adamow[2], P. Zielinski[2], G. Maciejewski[2]

[1]*Pennsylvania State Univ.,* [2]*Torun Center for Astronomy, Poland.*

2:30 PM - 2:50 PM

We present the discovery of sub-stellar mass companions to six giant stars by the ongoing Penn State-Torun Planet Search conducted with the Hobby-Eberly Telescope. Each system has a single planet, with minimum masses ranging from 0.9 to 5.3 MJ and orbits ranging from 0.9 to 5.6 years, the longest period yet found by our survey. Three other stars exhibit long-term non-linear RV trends, indicative of additional companions that may be low-mass stars or brown dwarfs. If these companions prove to be

substellar, they add to a growing number of companions to giants that have minimum masses in excess of 10 MJ, making them candidates for either brown dwarfs or supermassive planets.

Such systems may require a gravitational instability in the circumstellar disk to form. The two remaining stars have significant RV noise due to intrinsic stellar variability, making it more difficult to detect a low-amplitude periodic signal. If the noise component of the observed RV variations is due to solar-type oscillations, we show, using all the published data for the substellar companions to giants, that its amplitude is anti-correlated with stellar metallicity. It is not yet clearly established whether the metallicity - planet frequency correlation observed in dwarfs also holds for giants, though the apparent increase in RV noise for low-metallicity giants must bias these studies.

125.04 – **New Transiting Planet Surveys in the High Canadian Arctic**

Nicholas M. Law[1], S. Sivanandam[1], R. Carlberg[1], R. Murowinski[2], E. Steinbring[3]

[1]University of Toronto, Canada, [2]Rick.Murowinski@nrc-cnrc.gc.ca, Canada, [3]NRC Herzberg Institute of Astrophysics, Canada.

2:50 PM - 3:00 PM

We describe a transiting planet and stellar variability survey to be performed in the high Canadian Arctic. The new observatory, which will be located at the Ellesmere Island PEARL Station at 80 degrees latitude, offers 24-hour darkness, excellent observing conditions, and long clear-sky periods. Compared to mid-latitude sites these advantages give greatly improved transit detection efficiency for longer-period, potentially habitable planets around cool stars. The survey has two components: a 20-inch robotic 1-square-degree imaging telescope, and two 200-square-degree 85mm telescopes pointed at Polaris. The telescopes and observatory infrastructure are currently under construction and the survey is planned to begin in 2012.

125.05 – **Subaru SEEDS Survey of Exoplanets and Disks**

Michael W. McElwain[1], SEEDS collaboration

[1]NASA Goddard Space Flight Center.

3:00 PM - 3:10 PM

The Strategic Exploration of Exoplanets and Disks at Subaru (SEEDS) is the first strategic observing program (SSOPs) awarded by the National Astronomical Observatory of Japan (NAOJ). SEEDS targets a broad sample of stars that span a wide range of masses and ages to explore the formation and evolution of planetary systems. This survey has been awarded 120 nights over five years time to observe nearly 500 stars. Currently in the second year, SEEDS has already uncovered exciting new results for the protoplanetary disk AB Aur, transitional disk LkCa15, and nearby companion to GJ 758. We present the survey architecture, performance, recent results, and the projected sample. Finally, we will discuss planned upgrades to the high contrast instrumentation at the Subaru Telescope.

125.06 – **The KELT Survey for Transiting Planets around Bright Stars**

Joshua Pepper[1], R. J. Siverd[1], R. Kuhn[2], T. Beatty[3], S. Gaudi[3], K. Stassun[1], J. Eastman[3]

[1]Vanderbilt University, [2]The University of Cape Town, South Africa, [3]The Ohio State University.

3:10 PM - 3:20 PM

The KELT project is a transit survey using two robotic, wide-field, small aperture telescopes, with the primary goal of discovering transiting exoplanets of bright ($8 < V < 11$) stars. Transiting planets around bright stars are accessible to intensive followup observations at extremely high signal-to-noise, and are the best individual laboratories for studying planet atmospheres and compositions. Discoveries of new bright-star transits are hence of great scientific value. In Arizona, KELT-North has been running for 5 years, and in South Africa KELT-South has been running for 1.5 years. The KELT pipeline implements a modified version of the ISIS difference imaging software package and achieves the required (< 1% RMS) precision to detect Jupiter-sized transiting planets for the typical host stars in our sample. The data are also being used to create catalogs of variable stars, identify EBs for testing stellar astrophysics, and to acquire lightcurves of inner solar system comets. The KELT team is currently following up transit candidates and the KELT data set has potential value for future exoplanet surveys.

The KELT project has received funding from the Vanderbilt Initiative in Data-intensive Astrophysics (VIDA), NSF PAARE grant AST-0849736, NASA Grant No. NNG04G070G, and from NSF CAREER Grant AST-1056524.

125.07 – **First Science Results From Planethunters.org: A Citizen Science Analysis Of Kepler Data.**

Chris Lintott[1], M. Schwamb[2], D. Fischer[2], M. Giguere[2], S. Lynn[3], J. Brewer[2], M. Parrish[3], K. Schawinski[2], R. Simpson[1], A. Smith[3], J. Spronck[2]

[1]University of Oxford, United Kingdom, [2]Yale University, [3]Adler Planetarium.

3:20 PM - 3:30 PM

Planet Hunters (http://www.planethunters.org), part of the Zooniverse collection of citizen science projects, enlists the general public to visually identify transits in the publicly released Kepler data via the World Wide Web. The human eye and brain are well suited to picking out most transits that cannot be detected in periodograms and are missed by the automated search algorithms. With over 53,000 volunteers examining the light curves on the Planet Hunters interface, we have the ability to visually inspect the entire public dataset for signatures of exoplanet transits. Planet Hunters is thus a novel and complementary technique to the automated transit detection algorithms, providing an independent assessment of the completeness of the Kepler exoplanet inventory.

For each of the ~150,000 Kepler-monitored stars, approximately 10 users examine 30-day segments of the star's light curve, identifying potential transits. Planet Hunters classifications are processed through a pipeline which uses simulated transit light curves to assess the capabilities of individual volunteers. Weightings are assigned to individuals and an iterative process is used to converge on final classifications and identify planet candidates. We present the results from analyzing the first three quarters of Kepler observations (~120 days of observations) and present planet candidates identified by Planet Hunters comparing to the Kepler team's published lists of planet candidates. In particular, we discuss the abundance of large planets (> 2 earth radii) on short period (< 15 days) orbits based on Planet Hunters detections.

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126 – Supernovae I

Oral Session – Ballroom E – Monday, January 9, 2012, 2:00 PM - 3:30 PM

126.01D – **The Lick Observatory Supernova Search: Analysis of 165 Nearby Type Ia Supernova Light Curves**

Mohan Ganeshalingam[1], W. Li[1], A. V. Filippenko[1]

[1]UC Berkeley.

2:00 PM - 2:20 PM

I will present the first data release of BVRI light curves for 165 nearby Type Ia supernovae (SNe Ia) from the Lick Observatory Supernova Search (LOSS) along with our analysis. The LOSS observations represent a high-quality dataset that can be used to probe the physics of SNe Ia as well as refine their use as cosmological standardizable candles. Drawing mostly from the LOSS sample, I will discuss our results from an analysis of the rise-time distribution of nearby SNe Ia and its dependence on spectroscopic subtype. In addition, we place constraints on the SNe Ia progenitor system using the earliest photometry epochs to search for signs of interaction with a companion star. I will also present results from a cosmological analysis utilizing the LOSS data which are a significant addition to the number of nearby SN Ia light curves. This research was supported by NSF grant AST-0908886 and the TABASGO Foundation.

126.02 – **Studies of Twin Supernovae with the Nearby Supernova Factory**

Hannah Fakhouri[1], G. Aldering[2], P. Antilogus[3], C. Aragon[2], S. Bailey[2], C. Baltay[4], S. Bongard[3], C. Buton[5], A. Canto[3], F. Cellier-Holzem[3], M. Childress[1], N. Chotard[6], Y. Copin[6], E. Gangler[6], J. Guy[3], E. Hsiao[7], M. Kerschhaggl[5], M. Kowalski[5], P. Nugent[8], K. Paech[5], R. Pain[3], E. Pecontal[9], R. Pereira[6], S. Perlmutter[10], D. Rabinowitz[4], M. Rigault[6], K. Runge[2], R. Scalzo[11], G. Smadja[6], C. Tao[12], R. Thomas[8], B. Weaver[13], C. Wu[14]

[1]UC Berkeley / LBL, [2]Physics Division, Lawrence Berkeley National Laboratory, [3]Laboratoire de Physique Nucleaire et des Hautes Energies Universite Paris Diderot Paris 7, France, [4]Department of Physics, Yale University, [5]Physikalisches Institut, Universitat Bonn, Germany, [6]Universite de Lyon, France, [7]Carnegie Observatories, [8]Computational Cosmology Center, Computational Research Division, Lawrence Berkeley National Laboratory, [9]Centre de Recherche Astronomique de Lyon, Universite Lyon 1, France, [10]Physics Division, Lawrence Berkeley National Laboratory, University of California Berkeley, [11]Research School of Astronomy and Astrophysics, The Australian National University, Australia, [12]Tsinghua Center for Astrophysics, Tsinghua University, China, [13]Center for Cosmology and Particle Physics, New York University, [14]National Astronomical Observatories, Chinese Academy of Sciences, China.

2:20 PM - 2:30 PM

We report on the latest developments in a study of "twin" supernovae with spectrophotometric timeseries of nearby Type Ia supernovae from the Nearby Supernova Factory. Two SNe Ia are considered twins if they have matching spectrophotometry at all epochs, though allowing a single multiplicative ratio to account for relative overall brightness difference (i.e. the difference between the Hubble residuals). We expect this luminosity distance-corrected brightness difference to be

minimal for twin SNe, allowing further standardization of these cosmologically useful tools. One novel aspect in this report is the use of Gaussian process regression to model the SN spectral surface, allowing a direct statistical comparision of SN pairs and the interpolation of the data to a uniform epoch sampling.

126.03D – **The Berkeley SuperNova Ia Program (BSNIP): Dataset and Initial Analysis**

Jeffrey Silverman[1], M. Ganeshalingam[1], J. Kong[1], W. Li[1], A. Filippenko[1]

[1]*University of California, Berkeley.*

2:30 PM - 2:50 PM

I will present spectroscopic data from the Berkeley SuperNova Ia Program (BSNIP), their initial analysis, and the results of attempts to use spectral information to improve cosmological distance determinations to Type Ia supernova (SNe Ia). The dataset consists of 1298 low-redshift ($z < 0.2$) optical spectra of 582 SNe Ia observed from 1989 through the end of 2008. Many of the SNe have well-calibrated light curves with measured distance moduli as well as spectra that have been corrected for host-galaxy contamination. I will also describe the spectral classification scheme employed (using the SuperNova Identification code, SNID; Blondin & Tonry 2007) which utilizes a newly constructed set of SNID spectral templates. The sheer size of the BSNIP dataset and the consistency of the observation and reduction methods make this sample unique among all other published SN Ia datasets.

I will also discuss measurements of the spectral features of about one-third of the spectra which were obtained within 20 days of maximum light. I will briefly describe the adopted method of automated, robust spectral-feature definition and measurement which expands upon similar previous studies. Comparisons of these measurements of SN Ia spectral features to photometric observables will be presented with an eye toward using spectral information to calculate more accurate cosmological distances. Finally, I will comment on related projects which also utilize the BSNIP dataset that are planned for the near future.

This research was supported by NSF grant AST-0908886 and the TABASGO Foundation. I am grateful to Marc J. Staley for a Graduate Fellowship.

126.04 – **Stripped Core-Collapse SNe: First Large and Systematic Spectroscopic Data Set**

Maryam Modjaz[1]

[1]*New York University.*

2:50 PM - 3:00 PM

The study of Stripped-Envelope Core-Collapse SNe (Stripped SNe) is vital for a number important areas in astrophysics, from understanding the diverse deaths of massive stars, to the connection between SNe and Long-duration Gamma-ray bursts to quantifying and excluding contaminants in high-z SNe Ia searches for cosmology. However, the study of Stripped SNe has been confined to a handful of well-observed individual objects that happened to be nearby or peculiar. While the SNe Ic-bl associated with long Gamma Ray Bursts (GRBs) have been studied in detail, the full range of properties of normal or broad-lined SNe is not known, nor their dominant progenitor channel and the productions conditions that lead to different kinds of explosions in massive stars. Stripped-envelope core-collapse supernovae (i.e., SNe of Type IIb, Ib, Ic and broad-lined Ic) are supernovae whose massive progenitors have been stripped of progressively larger amounts of their hydrogen and helium envelopes.

Here, I present densely time-sampled and homogeneous spectroscopic data of about 30 supernovae of Type IIb, Ib, Ic and Ic-bl, which triples the world supply of well-observed Stripped SNe. I will also discuss the analysis of their spectra and those from the literature in form of a systematic and statistically thorough fashion. I will also briefly mention the most recent results on SN environments, specifically on measured metallities, and what they may tell us about the progenitors of Stripped SNe.

126.05D – **Hubble Residual Correlations with Spectroscopic Host Properties from the SDSS-II Supernova Survey**

Christopher D'Andrea[1], R. Gupta[2], M. Sako[2], R. Nichol[1], H. Campbell[1], SDSS-II Supernova Survey

[1]*Institute for Cosmology and Gravitation, University of Portsmouth, United Kingdom,* [2]*University of Pennsylvania.*

3:00 PM - 3:20 PM

It is well known that the most luminous Type Ia supernovae (SNe Ia) occur preferentially in galaxies with low mass and high star-formation rates. This is an important effect for SN cosmology only if the standard SNe Ia luminosity correlation with light-curve shape and color are affected by differences in environment. In the past few years several groups have shown that environment does appear to matter; that residuals on the Hubble Diagram are correlated with host galaxy mass, metallicity, and star-formation rate. We study this effect in a new way with SNe Ia discovered as part of the SDSS-II Supernova Survey. In contrast to previous works that use photometric estimates of host mass as a proxy for global metallicity, we analyze spectra of emission-line host galaxies to obtain gas-phase metallicities and star-formation rates. We restrict our analysis to SNe at redshifts $z < 0.15$, where the selection effects of the survey are known to yield a complete SNe Ia sample. We also minimize the bias in our sample with respect to measured host-galaxy properties by obtaining spectra for nearly all hosts, spanning a range in absolute magnitude of $-23 < Mr < -17$. From a final sample of 33 galaxies, we find that light-curve corrected SNe Ia are 0.11 magnitudes brighter in the mean in high-metallicity hosts than in low-metallicity hosts. We also find a significant correlation between the Hubble residuals of SNe Ia and the specific star-formation rate of the host galaxy. As the statistics of well-observed SNe Ia at high redshift increases, the evolution of the typical environment with respect to the local sample could become a key source of systematic bias.

126.06 – **On the Explosion Geometry of Red Supergiant Stars**

Douglas C. Leonard[1], L. Dessart[2], D. Hillier[3], G. Pignata[4]

[1]*San Diego State University,* [2]*Laboratoire d'Astrophysique de Marseille, France,* [3]*University of Pittsburgh,* [4]*Univeridad Andres Bello, Chile.*

3:20 PM - 3:30 PM

From progenitor studies, type II-Plateau supernovae (SNe II-P) have been decisively and uniquely determined to arise from isolated red supergiant stars, establishing the most homogeneous --- and well understood --- progenitor class of any type of core-collapse supernova. The precise nature of the mechanism responsible for the stellar explosion, however, remains the subject of considerable debate. A fundamental clue to the nature of the explosion mechanism is explosion geometry: In short, are supernovae round? Because young supernova atmospheres are electron-scattering dominated, their net linear polarization provides a direct probe of early-time supernova geometry, with higher degrees of polarization generally indicating greater departures from spherical symmetry.

Here we present spectropolarimetry data for the most well-sampled SN II-P to date, SN 2008bk, and compare (and contrast) the results with those obtained for SN 2004dj, the only other SN II-P for which spectropolarimetry data were obtained with similar fine temporal sampling before, during, and after the fall off of the photometric plateau (Leonard et al. 2006). Both objects are polarized, indicating departures from spherical symmetry, although the timing of the onset -- as well as the persistence -- of the polarization differ between the two objects. Curiously, the detailed spectropolarimetric characteristics of the two objects at the epochs of recorded maximum polarization are extremely similar, feature by feature, suggesting a common cause --- or, at least, geometry. We interpret the data in light of non-Local-Thermodynamic Equilibrium, time-dependent radiative-transfer simulations specifically crafted for SN II-P ejecta.

DCL acknowledges support from NSF grant AST-1009571, under which part of this research was carried out. Based on observations collected at the European Organisation for Astronomical Research in the Southern Hemisphere, Chile, under observing programs 081.D-0128, 082.D-0151, and 085.D-0391 (PI: Dessart).

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127 – HEAD: The Variable and Surprising Gamma-ray Sky

Special Session – Room 18B – Monday, January 9, 2012, 2:00 PM - 3:30 PM

The Fermi Gamma-ray Space Telescope is providing a new way toview the gamma-ray sky. Its two instruments survey the full skyevery three hours over an energy range spanning seven orders ofmagnitude. The high sensitivity offers the opportunity for timedomain astronomy at gamma-ray energies, measuring variability onscales ranging from milliseconds to years. Dramatic results ongamma-ray bursts, pulsars, high-mass binary systems, and active galacticnuclei have emerged from the Fermi capabilities. Transientsinclude flares from the Crab Nebula, a symbiotic binary nova, and the Sun,while the deepening exposures have revealed unexpected details of giantGalactic bubbles, supernova remnants, and pulsar wind nebulae.

127.01 – **Expecting the Unexpected with the Fermi Gamma-ray Space Telescope**

David John Thompson[1]

[1]*NASA's GSFC.*

2:00 PM - 2:22 PM

With their huge fields of view, the scientific instruments on the Fermi Gamma-ray Space Telescope survey the entire sky every three hours, watching for changes on time scales ranging from fractions of a second to years. The operational flexibility of the Fermi spacecraft allows pointing as well as survey modes, so that the full power of the observatory can be brought to bear on targets of interest. Gamma-ray bursts can trigger automated repoints of the satellite. Planned pointed observations can be coordinated with multiwavelength campaigns to search for coordinated variability. Target of Opportunity repointings are possible on short time scales to allow quick response to

unexpected activity in the sky. The mission uses a variety of techniques to inform the scientific community of surprising activity.

127.02 – **Gamma Ray Activity in the Galaxy - Pulsars, Novae, Binaries and Supernova Remnants**

Roger D. Blandford[1]

[1]*Stanford University.*
2:22 PM - 2:44 PM

Fermi Gamma Ray Space Telescope has been remarkably successful in studying variable Galactic sources. It has discovered over a hundred pulsars and is helping us understand how they work and can serve as tools. It has found remarkable variability in the Crab Nebula whose explanation may have ramifications for many other high energy sources. It has detected a nova outburst raising important questions about their role in stellar evolution. It has monitored neutron star binaries and microquasars which exhibit particle acceleration in unfamiliar environments. Finally, it has studied individual supernova remnants clarifying our understanding of the acceleration of cosmic rays and suggesting a connection to the "bubbles" reported from our Galactic center. These and other discoveries will be reviewed.

127.03 – **Constant Change: Understanding Black Holes Through Observations Of AGN Jets**

Grzegorz Maria Madejski[1]

[1]*Stanford Linear Accelerator Ctr..*
2:44 PM - 3:06 PM

Owing to its all-sky monitoring capability, Fermi LAT continues to provide us with unprecedented sampling of gamma-ray flux from celestial objects. This is particularly valuable for the highly variable jet-dominated active galaxies, where Fermi LAT is sensitive in the spectral regime often responsible for the largest fraction of total radiated power. Since those objects radiate in all accessible energy regimes, major breakthroughs have been gleaned from time-resolved multi-band observations including the gamma-rays but also radio, IR, optical, UV and X-ray bands. In this presentation I will cover the results of temporal studies of blazars with Fermi LAT - including the analysis of gamma-ray time series via studies of Power Density Spectra and duty cycles of flaring activity - but also variability properties across the entire electromagnetic spectrum. This will highlight the time-resolved optical polarization properties as well as X-ray measurements simultaneous with Fermi LAT, providing the constraints on the emission processes as well as the structure, content, and geometry of AGN jets, and their connection to the central black hole.

127.04 – **Cosmic Explosions: Exploring the Most Extreme Gamma-ray Bursts**

Stephen B. Cenko[1]

[1]*University of California, Berkeley.*
3:06 PM - 3:28 PM

With 7 decades in energy coverage, the Fermi satellite has opened a new window into the study of gamma-ray bursts (GRBs): the MeV/GeV regime. In the first part of my talk, I will provide a brief overview of the many exciting GRB results from Fermi to date, including the detection of a long-lived (≈ 1000 s) GeV ``afterglow'' from several events, and the discovery and theoretical implications of additional (possibly photospheric) emission components in several prompt high-energy GRB spectra. In the second half, I will describe how Fermi provides an incredibly efficient way to target the most luminous GRBs in the universe, and what observations of the broadband afterglows of these sources reveal about the geometry, beaming-corrected energetics, circumburst environments, and progenitor systems of these explosions.

128 – Career Panel: Career Paths

Special Session – Ballroom G – Monday, January 9, 2012, 2:00 PM - 3:30 PM

The purpose of this panel discussion is to inform recent and upcoming graduates of careers other than the traditional professor/academic track that is typically (and incorrectly) assumed to be the natural outcome of an advanced degree in physics or astronomy. Our panelists (listed below) include representatives from public outreach, community college and education, public policy, and industry. The session will include brief introductions by each of the panelists about their careers, the skills which have enabled them to be successful, and suggestions for how to follow a similar career path. The discussion will be driven by questions from the audience. Time will be reserved at the end for small group discussions with the panelists.

Panelists:
Dave Finley, Public Information Officer for the National Radio Astronomy Observatory
Rica Sirbaugh French, Mira Costa College and NASA Center for Astronomy Education
Pat Slane, Harvard-Smithsonian Center for Astrophysics
Nick Suntzeff, Texas A&M and the State Department
Gautam Vasisht, Jet Propulsion Laboratory, California Institute of Technology.

128.00C – **Chair**

Kelle L. Cruz[1]

[1]*Hunter College/CUNY & AMNH.*

129 – Evolution of Galaxies II

Oral Session – Room 19A – Monday, January 9, 2012, 2:00 PM - 3:30 PM

129.01 – **The Faint Population Of Lyman-alpha Emitting Galaxies At Redshift 5.7**

Alaina L. Henry[1], C. L. Martin[1], A. Dressler[2], P. McCarthy[2], M. Sawicki[3]

[1]*UC, Santa Barbara,* [2]*Carnegie Observatories,* [3]*Saint Mary's University, Canada.*
2:00 PM - 2:10 PM

Using new Keck DEIMOS spectroscopy, we examine our recent evidence (reported in Dressler et al. 2011) for a steep rise in the number counts of ultra-faint Lyman α emitters (LAEs) at redshift 5.7. With six newly confirmed LAEs, we revise our previous estimate of the numbers of ultra-faint LAEs and foreground emission-line galaxies. Combining these data with the density of bright LAEs in the Cosmic Origins Survey and the Subaru Deep Field provides the best constraints to date on the redshift 5.7 Lyman α luminosity function (LF). To place this result in the context of the UV-selected galaxy population, we investigate how various parameterizations of the equivalent width distribution, along with the measured UV-continuum LF, affect the shape and normalization of the Lyman α LF. The nominal model, which uses the z~6 equivalent width distributions reported by Stark et al. (2011), falls short of the observed space density of LAEs at the bright end, possibly indicating a need for higher equivalent widths. Futhermore, this parameterization of the equivalent width distribution implies that as many as 50% of our faintest LAEs should have M(UV) > -18.0, rendering them undetectable in even the deepest Hubble Space Telescope surveys at this redshift. Hence, ultra-deep emission-line surveys find some of the faintest galaxies ever observed at the end of the reionization epoch. Such faint galaxies likely enriched the intergalactic medium with metals and maintained its ionized state. Observations of these objects provide a glimpse of the building blocks of present-day galaxies at an early time.

129.02 – **Searching for High-redshift Lyα Emitters in the COSMOS Field with NEWFIRM**

Hannah B. Krug[1], S. Veilleux[1], V. Tilvi[2], S. Malhotra[3], J. Rhoads[3], P. Hibon[4], R. Swaters[5], R. Probst[5], A. Dey[5], M. Dickinson[5], B. Jannuzi[5]

[1]*University of Maryland,* [2]*Texas A&M University,* [3]*Arizona State University,* [4]*Gemini Observatory, Chile,* [5]*NOAO.*
2:20 PM - 2:30 PM

The study of Lyα emission in the high-redshift universe is a useful probe of the epoch of reionization, as the Lyα line should be attenuated by the intergalactic medium if the local neutral hydrogen fraction is over 50%. Here we discuss the results of a deep and wide imaging search for Lyα emitters in the COSMOS field. We have used two ultra-narrowband filters (filter widths of ~8 and 9 AA) on the NEWFIRM camera, installed on the Mayall 4m telescope at Kitt Peak National Observatory, in addition to public archival broadband optical and near-IR imaging data, in order to isolate Lyα emitters at z = 7.7; such ultra-narrowband imaging searches have proven to be excellent at detecting Lyα emitters. We have found 5σ detections of four candidate Lyα emitters in a survey volume of 2.8×10^4 Mpc^3. Each candidate has a line flux greater than 8×10^{-18} $erg/s/cm^2$. We have used these results to construct a Lyα luminosity function, which we

compare to previously established Lyα luminosit functions at z = 5.7 and z = 6.5. We discuss the impact of our findings on the evolution of the Lyα luminosity function between 5.7 < z < 7.7 and what we may conclude from that regarding the epoch of reionization.

129.03D – **The Stelar Mass Growth of Galaxies between z~8 and z~4**

Valentino Gonzalez[1], R. Bouwens[2], I. Labbe[2], G. Illingworth[1], P. Oesch[1]

[1]*University of California Santa Cruz,* [2]*Leiden University, Netherlands.*

2:30 PM - 2:50 PM

The recent deep and ultra-deep surveys with the HST WFC3/IR camera have resulted in the deepest ever near-IR images. Combined with the deepest optical images from the HST ACS camera, and the deep wide area Spitzer/IRAC mid-IR images from the GOODS-S, these represent a remarkable dataset that has produced very large samples of high redshift galaxies over a wide range of luminosities. From this dataset it has been possible to obtain fairly robust estimates of the properties of these galaxies, in particular, their star formation rates and stellar masses. Early results include the realisation that in high-z Lyman Break Galaxies the total SFR correlates with the Stellar Mass. This "main sequence" of star forming galaxies has been observed at lower redshifts but contrary to what is observed there, this relation does not seem to evolve at z>4-7, which posses an interesting puzzle to theory, sometimes referred to as the specific SFR plateau. This dataset has also resulted in the best estimates of the galaxy stellar mass functions at z~4-7 which now places interesting constraints on numerical simulations, particularly at low masses (~10^8 Msun). The integral of these stellar mass functions also provide estimates of the stellar mass density of the Universe at different redshifts that can be compared to the values expected from the UV-derived star formation rate densities. In this presentation I will review these results including the latest progress and will discuss what these observations suggest regarding the way in which galaxies grew in the early Universe.

129.04 – **Very Luminous Galaxy Population at z > 7 as Revealed by HIPPIES**

Haojing Yan[1], HIPPIES Collaboration

[1]*University of Missouri - Columbia.*

2:50 PM - 3:00 PM

We present the new results from the Hubble Infrared Pure Parallel Imaging Extragalactic Survey (HIPPIES), which utilizes HST pure parallel orbits to do deep, multi-band optical/IR imaging along a large number of random sightlines. One of the key goals of HIPPIES is to search for the most luminous candidate galaxies at z > 7 and to address the very bright-end of the luminosity function at these redshifts using a sample that is the least affected by "cosmic variance". Our initial results have been reported in Yan et al. (2011) and at the 217th AAS meeting. Here we report the progress of our program, which includes (1) the additional, bright Y098-dropouts discovered in the Cycle-17 data that we have acquired after 2011 January, and (2) the new, similarly bright Y105-dropouts found in the Cycle-18 data. We do NOT confirm the z ~ 8 overdensity that recently claimed by Trenti et al. (2011), who have used the same Cycle-17 data. However, we report possible overdensities found in different fields, and stress that the results based on a limited number of contiguous fields (albeit large) could be severely affected by the "cosmic variance". The authors acknowledge the support of NASA grants HST-GO-11702.* and HST-GO-12286.*.

129.05D – **"Observing" Images of a Simulated Universe: the High Redshift Luminosity Function**

Robert J. Morgan[1], E. Scannapieco[1], R. A. Windhorst[1], R. Thacker[2]

[1]*Arizona State Univ.,* [2]*St. Mary's University, Canada.*

3:00 PM - 3:20 PM

Observational tools and techniques are used to analyze the output of cosmological numerical simulations to obtain luminosity functions (LFs) of galaxies and galactic building blocks formed in the simulation. The simulations, (a version of Gadget-2, Springel and Hernquist, 2003), use both dark and baryonic matter components, with gasdynamics and star formation to minimize assumptions. The stellar particle output of the simulation at various redshifts is coupled to the Bruzual-Charlot (2003) stellar population synthesis models to create image files in various simulated IR filters for processing by Source Extractor.

The slopes of the luminosity function (LF) over the range of z~4.5 to 11.0 are compared with observational results with good agreement as to the slope “alpha” of the LF curve. Realistic sky background levels are added to the image files to permit better comparisons with observations and to show the effect on the analysis of simulation results.

We are grateful to the ASU Advanced Computing Center (A2C2) for providing computer time.

129.06 – **Were Progenitors of L* Galaxies Lyman-alpha Emitters At High Redshift?**

Hidenobu Yajima[1], Y. Li[1], Q. Zhu[1]

[1]*Pennsylvania State University.*

3:20 PM - 3:30 PM

The Lyman-alpha emission from galaxies has been observed over redshift z = 0 - 9. However, the link between high-redshift Lyman alpha emitters (LAEs) and local galaxies is largely unknown. Here, we investigate the Lya properties of progenitors of a local L* galaxy by combining cosmological hydrodynamic simulations and three-dimensional radiative transfer calculations.

We find that the modeled galaxies are Lya bright in the redshift range 0 < z < 10. In particular, their Lya luminosities are close to the observed characteristic L_{Lya}^* of LAEs at z~2-6. Furthermore, the Lya emission by excitation cooling increases with redshift, accounting ~ 50 % of the total at z > 6. Our results suggest that Lya emission from cold gas accretion dominates at high redshift, and that the observed LAEs at z~2-6 may evolve into a Milky Way-like galaxy at present day.

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130 – The Dark Universe Viewed by CFHTLenS

Special Session – Room 18C – Monday, January 9, 2012, 2:00 PM - 3:30 PM

Dark Matter and Dark Energy constitute over 95% of the energy density of the Universe, and determining their nature constitutes the major challenge for cosmology over the next decade. This special session will present the first results from the complete Canada-France-Hawaii Telescope Lensing Survey reviewing the successes and challenges of the world's most competitive lensing survey. Weak gravitational lensing is a powerful technique that can map Dark Matter structures from its gravitational effects alone and probe Dark Energy through its effect on the growth of these structures. Its potential is only reached when systematic errors are under control as demonstrated by the completely new methodology for data, photometric redshifts and weak lensing analysis of CFHTLenS. The CFHTLenS view on the Dark Universe spans for the first time the complete range from dark matter haloes, through groups and clusters to the largest scales that Dark Matter has ever been observed. With a full 3-D analysis CFHTLenS also puts Dark energy and modified gravity theories to the test.

130.01 – **The CFHT Lensing Survey**

Catherine Heymans[1], CFHTLenS Collaboration

[1]*Institute for Astronomy, University of Edinburgh, United Kingdom.*

2:00 PM - 2:13 PM

We present the Canada-France-Hawaii Telescope Lensing Survey (CFHTLenS). This survey spans 155 square degrees in five ugriz optical bands incorporating data from the Wide, Deep and Pre-Imaging components of the CFHT-Legacy Survey. Applying our new methodology for data processing, photometric redshifts and weak lensing measurement to bring systematic errors under control, we present robust measurements of weak gravitational lensing and cosmological constraints.

130.02 – **Mapping of Dark Matter in Large Scale Structures**

Ludovic Van Waerbeke[1], CFHTLenS collaboration

[1]*University of British Columbia, Canada.*

2:13 PM - 2:26 PM

We present the largest mass maps ever made with gravitational lensing. The maps unveil the distribution of dark matter in cosmic structures over the four patches of CFHT Lensing Survey (CFHTLenS) covering 155 square degrees. Some structures that span a few degrees in extension are clearly visible on the maps. The mass maps are for the first time used to probe cosmological parameters. A comparison with the projected mass as expected from the stellar masses of foreground galaxies and clusters will also be discussed.

130.03 – **Weak Lensing Shape Measurement in CFHTLenS**

Lance Miller[1], CFHTLenS Collaboration

[1]*Oxford University, United Kingdom.*

2:26 PM - 2:36 PM

We describe lensfit, a bayesian fitting method, which has been used to measure weak lensing shear in the CFHT Lensing Survey (CFHTLenS). We discuss the mathematical principles of the method and the solutions to some of the issues that make shear measurement in ground-based surveys particularly challenging: the correction of

complex shaped point spread functions (PSFs) that vary with position and time, the need to optimally combine multiple exposures obtained with differing PSFs, and the challenge of PSF correction on galaxies whose sizes are comparable to or smaller than that of the PSF. Lessons learned from CFHTLenS will be valuable for future large-area lensing surveys.

130.04 – **Weak Lensing Magnification Measurements in CFHTLenS**

Hendrik Hildebrandt[1], CFHTLenS Collaboration (http://www.cfhtlens.org)

[1]*University of British Columbia, Canada.*
2:36 PM - 2:46 PM

Weak lensing magnification is an emerging technique to study the dark sector of the Universe, especially at high redshifts. The unique CFHT Lensing Survey (CFHTLenS based on the raw data of the CFHTLS) data set has the quality to carry out the first astrophysically relevant magnification measurements. First I will summarise the efforts that went into the photometric redshift estimation in CFHTLenS, an indispensable ingredient not only for magnification-based but also for shear-based science projects. Then I will present measurements of the magnitude-shift induced by galaxies up to redshifts of z~1.4 which allow us to estimate their average dark matter and dust halos. I will give an outlook and show mass estimates of high-redshift clusters and cosmological measurements involving magnification tomography.

130.05 – **Dark Energy & 3D Cosmic Shear**

Thomas D. Kitching[1]

[1]*University of Edinburgh, United Kingdom.*
2:46 PM - 2:56 PM

In this presentation we present joint constraints on the dark energy equation of state as a function of redshift, and the sum of neutrino mass. We use an optimal approach, extracting all information from the data, using a full 3D spherical harmonic decomposition of the cosmic shear field. This is the first time such a technique has been applied to data.

130.06 – **Testing the Laws of Gravity with CFHTLenS and WiggleZ**

F. Simpson[1], CFHTLenS Collaboration, D. Parkinson[2], WiggleZ Collaboration

[1]*IfA, University of Edinburgh, United Kingdom,* [2]*University of Queensland, Brisbane, Australia.*
2:56 PM - 3:04 PM

The observed presence of dark energy may be the first sign of new physics in the Universe, either in the form of a matter-energy component or by revising Einstein gravity. Weak gravitational lensing and galaxy peculiar velocities provide complementary probes of modifications to General Relativity, and in combination allow us to test theories of gravity in a unique way. We perform such an analysis by combining measurements of the growth of structure from the WiggleZ Dark Energy Survey with cosmic shear tomography from CFHTLenS, producing the best existing constraints on the metric potentials that describe general theories of gravity.

130.07 – **Galaxy Dark Matter Halo Constraints in the CFHTLenS**

Malin Velander[1], CFHTLenS Collaboration

[1]*Leiden University, Netherlands.*
3:04 PM - 3:12 PM

Current theories of structure formation predict that galaxies are immersed in expansive dark matter haloes. To learn more about the baryon-dark matter connection it is therefore imperative to probe large scales as well as small. Weak galaxy-galaxy lensing has the power to do this since it not only is sensitive on a large range of scales, but also is independent of the type of matter studied. We present a study of large-scale galaxy dark matter halo properties as a function of the characteristics of the baryonic host galaxies using data from one of the largest completed weak lensing surveys to date, the CFHT Lensing Survey.

130.08 – **The Scale Dependent Galaxy Bias from CFHTLenS**

Christopher Bonnett[1]

[1]*CSIC/IEEC, Spain.*
3:12 PM - 3:20 PM

We present the latest result on the scale dependent galaxy bias in the CFHTLenS. Weak gravitational lensing provides a unique opportunity to study the total matter distribution between the source and the observer. Using this information we are able to measure the galaxy bias and the galaxy-matter correlation out to large scales with high precision in the CFHTLenS.

130.09 – **CFHTLenS - Data Handling and Public Data Products**

Thomas Erben[1], CFHTLenS Collaboration

[1]*AlfA, Bonn University, Germany.*
3:20 PM - 3:30 PM

Current and future Wide-Field Imaging Surveys allow us to use gravitational lensing for high-precision measurements of cosmological parameters and to study galaxy and cluster properties in great detail. To fully exploit the potential of current ground- and space-based imaging data we need to develop and to apply novel and fully automatic analysis techniques. This concerns the measurement of object properties such as photometry and shape parameters below the percent level and to establish a robust data-flow system in the Terabyte regime. In my presentation I will summarise the status of image-processing techniques in the context of the CFHTLenS (CFHT Lensing Survey) project.

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131 – AGN, QSO, Blazars II

Oral Session – Room 17A – Monday, January 9, 2012, 2:00 PM - 3:30 PM

131.01 – **Emission-Line Diagnostics of Nuclear Activity and Star Formation in Galaxies at 0<z<3 with CANDELS**

Jonathan R. Trump[1], B. J. Weiner[2], D. C. Koo[1], S. M. Faber[1], D. D. Kocevski[1]

[1]*UC Santa Cruz,* [2]*Arizona.*
2:00 PM - 2:10 PM

Rest-frame optical spectra contain a wealth of information about galaxy properties. In particular, the strengths and ratios between collisionally excited and recombination emission lines can be used to distinguish between star formation, shocks, and supermassive black hole accretion. The new HST/WFC3 near-IR slitless grism opens up a new realm for large studies of emission-line galaxies at z>1.5. We use CANDELS WFC3 grism observations to show that low-mass (log(M*/Msun)~9.5) galaxies at z~2 have emission line gradients suggestive of nuclear activity. We additionally combine CANDELS WFC3 grism spectroscopy with multiwavelength photometry and optical spectroscopy from AEGIS/DEEP and COSMOS to study the effectiveness of a full suite of emission line strengths and ratios in characterizing star formation, shocks, and nuclear activity in galaxies from 0<z<3.

131.02D – **Spectral Index Properties of millijansky Radio Sources in ATLAS**

Kate Randall[1], A. M. Hopkins[2], R. P. Norris[3], P. Zinn[4], E. Middelberg[4], M. Y. Mao[5], R. G. Sharp[6]

[1]*The University of Sydney/CSIRO Astronomy and Space Science, Australia,* [2]*Australian Astronomical Observatory, Australia,* [3]*CSIRO Astronomy and Space Science, Australia,* [4]*Ruhr-University Bochum, Germany,* [5]*University of Tasmania/CSIRO Astronomy and Space Science, Australia,* [6]*Research School of Astronomy and Astrophysics, Mount Stromlo Observatory, Australia.*
2:10 PM - 2:30 PM

At the faintest radio flux densities ($S_{1.4GHz}$ < 10 milliJansky (mJy)), the spectral index properties of radio sources are not well constrained. The bright radio source population ($S_{1.4GHz}$ > 10 mJy) is well studied and is predominantly comprised of AGN. At fainter flux densities, particularly into the microJansky regime, star-forming galaxies begin to dominate the radio source population. Understanding these faint radio source populations is essential for understanding galaxy evolution, and the link between AGN and star formation. Conflicting results have recently arisen regarding whether there is a flattening of the average spectral index between a low radio frequency (325 or 610 MHz) and 1.4 GHz at these faint flux densities. To explore this issue, we have investigated the spectral index properties of a new catalogue of 843 MHz radio sources in the ELAIS-S1 (the European Large Area ISO Survey - South 1 Region) field. Our results support previous work showing a tendency towards flatter radio spectra at fainter flux densities. This catalogue is cross-matched to the Australia Telescope Large Area Survey (ATLAS), the widest deep radio survey to date at 1.4 GHz, with complementary 2.3 GHz, optical and infrared Spitzer Wide-area Infra-Red Extragalactic data. The variation of spectral index properties have been explored as a function of redshift, luminosity and flux density. [These new measurements have been used to identify a population of faint Compact Steep Spectrum sources, thought to be one of the earliest stages of the AGN life-cycle. Exploring this population will aid us in understanding the evolution of AGN as a whole.

131.03 – **The Demographics Of Broad-line Quasars In The Mass-luminosity Plane**

YUE SHEN[1], B. C. Kelly[1]

[1]*Harvard-Smithsonian Center for Astrophysics.*
2:30 PM - 2:40 PM

We jointly constrain the luminosity function (LF) and black hole mass function (BHMF) of broad-line quasars using a Bayesian approach that describes the underlying active BHMF and Eddington ratio distribution to match the observed distributions in the quasar mass-luminosity plane, based on ~58,000 uniformly selected quasars from the SDSS

DR 7 at z~0.3-5. We take into account the selection effect of the sample flux limit; more importantly, we deal with the statistical scatter between true BH masses and FWHM-based single-epoch virial mass estimates, as well as potential luminosity-dependent biases of these mass estimates. The LF is tightly constrained in the regime sampled by SDSS quasars, and makes reasonable predictions when extrapolated to ~3 magnitudes fainter than the SDSS flux limit. Downsizing is seen in the model LF. On the other hand, we find it difficult to constrain the BHMF to within a factor of a few at z>~0.7 (when the virial mass estimator switches from Hbeta to MgII and CIV). This is mainly driven by the unknown luminosity-dependent bias of these virial mass estimators and its degeneracy with other model parameters, and secondly driven by the fact that SDSS quasars only sample the tip of the active BH population at high redshift. There is tentative evidence that downsizing also manifests itself in the active BHMF, and the BH mass density in broad-line quasars contributes an insignificant amount to the total BH mass density at all times. Within our model uncertainties, we do not find a strong BH mass dependence of the mean Eddington ratio; but there is evidence that the mean Eddington ratio (at fixed BH mass) increases with redshift. The luminosity-dependent bias and the statistical scatter between virial and true masses, combined with the sample flux limit, change the distribution in the mass-luminosity plane significantly.

131.04D – **Determining AGN Inclinations Via Narrow-Line Kinematics**

Travis C. Fischer[1]

[1]*Georgia State University.*
2:40 PM - 3:00 PM

Active Galactic Nuclei (AGN) are, to first order, axisymmetric systems in which their observed properties are strong functions of inclination with respect to our line of sight. However, except for a few special cases, the specific inclinations of individual AGN are unknown. Using high-resolution HST STIS spectra, I have modeled inclinations for 16 AGN from their narrow-line region (NLR) kinematics. As this study provides an early look on the varied inclinations of AGN, we can for the first time assess the effect of inclination on other observable parameters in radio-quiet AGN, including the discovery of a distinct correlation between AGN inclination and X-ray column density. As our line of sight with respect to the bicone axis increases, the torus surrounding the AGN becomes closer to edge-on and we see a seamless increase in column densities between Seyfert 1 and Seyfert 2 galaxies.

131.05D – **Parsec-Scale Radio Properties of Gamma-ray Bright Blazars**

Justin Linford[1]

[1]*University of New Mexico.*
3:00 PM - 3:20 PM

The parsec-scale radio properties of blazars detected by the Large Area Telescope (LAT) on board the Fermi Gamma-ray Space Telescope have been investigated using observations with the Very Long Baseline Array (VLBA). Comparisons between LAT and non-LAT detected samples were made using both archival and contemporaneous data. In total, 244 sources were used in the LAT-detected sample. This very large, radio flux-limited sample of active galactic nuclei (AGN) provides insights into the mechanism that produces strong gamma-ray emission. It has been found that LAT-detected BL Lac objects are very similar to the non-LAT BL Lac objects in most properties, although LAT BL Lac objects may have longer jets. The LAT flat spectrum radio quasars (FSRQs) are significantly different from non-LAT FSRQs and are likely extreme members of the FSRQ population. Archival radio data indicated that there was no significant correlation between radio flux density and gamma-ray flux, especially at lower flux levels. However, contemporaneous observations showed a strong correlation. Most of the differences between the LAT and non-LAT populations are related to the cores of the sources, indicating that the gamma-ray emission may originate near the base of the jets (i.e., within a few pc of the central engine). There is some indication that LAT-detected sources may have larger jet opening angles than the non-LAT sources. Strong core polarization is significantly more common among the LAT sources, suggesting that gamma-ray emission is related to strong, uniform magnetic fields at the base of the jets of the blazars. Observations of sources in two epochs indicate that core fractional polarization was higher when the objects were detected by the LAT. Included in our sample are several non-blazar AGN such as 3C84, M82, and NGC 6251.

131.06 – **Low-luminosity Blazars in Wise: A Mid-infrared View of Unification**

Richard M. Plotkin[1], S. F. Anderson[2], W. N. Brandt[3], S. Markoff[1], O. Shemmer[4], J. Wu[3]

[1]*Univ. of Amsterdam, Netherlands,* [2]*University of Washington,* [3]*Pennsylvania State University,* [4]*University of North Texas.*
3:20 PM - 3:30 PM

We use the preliminary data release from the Wide-Field Infrared Survey Explorer (WISE) to perform the first statistical study on the mid-infrared (IR) properties of a large number (~10^2) of BL Lac objects -- low-luminosity Active Galactic Nuclei (AGN) with a jet beamed toward the Earth. As expected, many BL Lac objects are so highly beamed that their jet synchrotron emission dominates their IR spectral energy distributions (SEDs), and the shape of their SEDs in the IR correlates well with SED peak frequency. In other BL Lac objects, the jet is not strong enough to completely dilute the rest of the AGN, and we do not see observational signatures of the dusty torus from these weakly beamed BL Lac objects. While at odds with simple unification, the missing torus is consistent with recent suggestions that BL Lac objects are fed by radiatively inefficient accretion flows. We discuss implications on the ``nature vs. nurture'' debate for FR I and FR II galaxies, and also on the standard orientation-based AGN unification model.

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132 – Binary Stellar Systems

Oral Session – Room 19B – Monday, January 9, 2012, 2:00 PM - 3:30 PM

132.01 – **BINSYN; a Publicly Available Version**

Albert P. Linnell[1], P. DeStefano[1]

[1]*Univ. of Washington.*
2:00 PM - 2:10 PM

A public version of the Binsyn program package now is available for download.

Binsyn is a set of programs, running on Linux, that simulate binary star systems, either with or without an optically thick accretion disk. The package includes facilities for parameter optimization by differentials correction. Light curve generation optionally is on the black body approximation or by synthetic photometry. In the latter case, the filter response curves provided with the release are on the Bessell, 1990, PASP, 102, 1181 (Table 2) tabulation. Substitution of different response curves to represent other photometric systems can be accomplished easily.

The package produces synthetic spectra and calculated radial velocities of system components as function of orbital phase for comparison with observational data. It has been used extensively in studies of cataclysmic variables (e.g., Linnell et al., 2010, ApJ, 719, 271).

The presentation will demonstrate program performance in a variety of contexts.

132.02D – **Taking a Closer Look at Massive Stars: A High Angular Resolution Survey of Cygnus OB2**

Saida M. Caballero-Nieves[1]

[1]*Georgia State University.*
2:10 PM - 2:30 PM

Massive stars profoundly influence the evolution of the universe, from galactic dynamics and structure to star formation, and they are frequently found with bound companions. However, our knowledge of O-type multiple systems with periods in the range from years to thousands of years is incomplete because of their great distance. We present results from a high angular resolution survey to find such astrometric companions using the Fine Guidance Sensor (FGS) on the Hubble Space Telescope and using ground-based adaptive optics at Gemini North. We observed 75 O- and early B-type stars in Cyg OB2 and determined that 42% of the sample have at least one companion that meets a statistical criterion for gravitationally bound status. We also present initial FGS results of a larger sample of Galactic O-stars that include association, cluster, field and runaway stars for a more representative multiplicity fraction of massive stars.

This material is based upon work supported by the National Science Foundation under grant AST-1009080 and the Space Telescope Institute under grant HST-GO-10612.

132.03 – **Heartbeat Stars: A Class Of Tidally Excited Eccentric Binaries**

Thomas Barclay[1], S. E. Thompson[2], F. Mullally[2], M. Everett[3], S. B. Howell[4], M. Still[1], J. L. Christiansen[2], J. Rowe[2], D. W. Kurtz[5], K. Hambleton[5]

[1]*NASA Ames Research Center/BAER Institute,* [2]*NASA Ames Research Center/SETI Institute,* [3]*University of Arizona,* [4]*NASA Ames Research Center,* [5]*University of Central Lancashire, United Kingdom.*
2:30 PM - 2:40 PM

We have discovered a class of eccentric binary systems undergoing dynamic tidal distortions and tidally induced pulsations in the Kepler data. Each has a uniquely shaped light curve that is characterized by periodic brightening or variability at time scales of 4-20 days which is frequently accompanied by shorter period oscillations. We can explain the dominant features of the entire class with changing tidal forces that occur in close, eccentric binary systems. In this case the large variety of light curve shapes arises from viewing systems at different angles. A hypothesis that is confirmed with radial velocity measurements that show an eccentric orbit.

Prior to the discovery of these 17 new systems, KOI-54 was the only system with direct detection of these dynamic tides and tidally induced oscillations. While significant work remains to include all the physics required to accurately model these systems and begin to understand how tidal effects influence the system, in this presentation we present preliminary fits to the light curves and describe the properties of this class of stars as a

whole.

132.04 – **Tidal Asteroseismology**

Joshua Burkart[1]

[1]*UC Berkeley.*
2:40 PM - 2:50 PM

The recently discovered Kepler system KOI-54 is a face-on eccentric binary consisting of two similar A stars. Its lightcurve exhibits ~20 tidally excited pulsations at perfect harmonics of the orbital frequency, and another ~10 nonharmonic pulsations. Analysis of such data is a new form of asteroseismology in which oscillation amplitudes and phases rather than frequencies contain information that can be mined to constrain stellar properties. I will discuss the physics of mode excitation and the range of harmonics expected to be observed. I will then show the results of numerical modeling of the pulsation spectrum, using a nonadiabatic stellar oscillation code including rotation in the "traditional approximation", which qualitatively reproduce the observations. I will discuss the evolutionary history of the KOI-54 system, and will show that the system is likely in a state of stochastic dynamical pseudosynchronization with stellar spin periods of ~1.5 days, significantly faster than the classical theoretical prediction of ~2.5 days. Time permitting, I will also address the nonharmonic pulsations observed in KOI-54, and show that they can be produced by nonlinear three-mode coupling.

132.05D – **Ultra-wide, Low-mass Binaries: Constraints on Binary Formation Theory and Calibration of Fundamental Stellar Parameters**

Saurav Dhital[1], K. G. Stassun[1], A. A. West[2]

[1]*Vanderbilt University,* [2]*Boston University.*
2:50 PM - 3:10 PM

We present results from the Sloan Low-mass Wide Pairs of Kinematically Equivalent Stars (SLoWPoKES) catalog of ultra-wide (10^3--10^5 AU), low-mass (K5--M7) common proper motion binaries. With 1342 disk dwarf, subdwarf, and white dwarf-red dwarf systems, this is the largest catalog of low-mass, wide binaries. A Galactic model, based on empirical stellar number density and space velocity distributions, was constructed to select only bona fide pairs with probability of chance alignment <5%, making SLoWPoKES an efficient sample for followup observations. We find in SLoWPoKES the presence of two populations of wide binaries, with a break at separations of ~0.1 pc: tightly bound systems that are expected to last 10 Gyr or longer and wide, weakly bound systems that are expected to dissipate within a few Gyr (based on binary disruption timescales from dynamical calculations). With physical separation as large as a parsec, the widest pairs may have been formed from evaporating stars during the dissipation of star-forming clusters. Based on our followup LGS-AO imaging observations of SLoWPoKES pairs, we found an overall higher-order multiplicity fraction of 45%. However, it is a strong function of binary separation: the fraction increases from 21% at the smaller wide binary separations to 77% at the largest separations, indicating that small N-body dynamics are important in explaining the formation of tight binaries.

From spectroscopic followup of 113 pairs, we confirm that the Lepine et al. zeta-index traces iso-metallicity loci for most of our sample of M dwarfs. However, we find a small systematic bias in zeta, especially in the early-type M dwarfs. We use our sample to recalibrate the definition of zeta. While representing a small change in the definition, the new zeta is a significantly better predictor of iso-metallicity for the higher mass M dwarfs.

132.06 – **Low-Mass Eclipsing Binaries from Kepler: Reaching the Natural Rotation Rates of M and K Dwarfs**

Jeffrey Coughlin[1], T. Harrison[1], M. Lopez-Morales[2], N. Ule[1]

[1]*New Mexico State Univ.,* [2]*Institut de Ciencies de l'Espai, Spain.*
3:10 PM - 3:20 PM

An outstanding problem in stellar astrophysics is that the radii of low-mass, main-sequence stars in eclipsing binary systems are consistently ~10-15% larger than predicted by stellar models. This inflation is hypothesized to be primarily due to enhanced magnetic activity as a result of their binarity, and thus artificially enhanced rotation rates. Thus, such an effect should diminish with increasing period, but only a small number of low-mass eclipsing binary systems are known in general, fewer are well-studied with precise light and radial-velocity curves, and barely any of these are at long periods. In addition to exploring the physics of low-mass stars, research into this area helps to better characterize the radii of extrasolar planets around low-mass stars, whose values are typically dependent on those assumed for the host star.

We have previously presented results from our search for new low-mass eclipsing binary systems via our Kepler Guest Observer programs and a search through the publicly available data. We identified over 100+ low-mass eclipsing binaries suitable for ground-based follow-up, with 30 of them having periods greater than 10 days, and found preliminary evidence for a trend of decreasing stellar radii with increasing orbital period.

In this presentation we present results of our ongoing effort to obtain ground-based multi-color light and radial velocity curves of these systems via the Kitt Peak National Observatory 4-meter, the Apache Point Observatory 3.5-meter, and New Mexico State University 1-meter telescopes. We also present preliminary modeling of these data combined with that from the Kepler mission, and examine what future work is needed to make progress in this area.

The presenter acknowledges funding from a National Science Foundation Graduate Research Fellowship.

132.07 – **Empirical Constraints on Common Envelope Evolution in Wide Binaries**

Aaron M. Geller[1], J. R. Hurley[2], R. D. Mathieu[3]

[1]*Northwestern University,* [2]*Swinburne University, Australia,* [3]*University of Wisconsin - Madison.*
3:20 PM - 3:30 PM

If a giant star in a binary overfills its Roche lobe, the giant's convective envelope may respond by expanding faster than its Roche lobe, transferring mass on a dynamical time scale, and creating a common envelope (CE) that engulfs both stars. Orbital energy may then be transferred from the binary to the envelope, which can shrink the orbit and drive away the material, leaving behind a detached system containing the white dwarf core of the giant. Such a CE event is thought to be critical for explaining certain populations of exotic stars (e.g., cataclysmic variables). Yet the application of CE evolution to binary population synthesis and N-body or Monte Carlo star cluster models requires many poorly constrained assumptions, which may lead to unphysical evolutionary paths. In fact, we find that such fictitious systems are created regularly within our N-body models of the old (7 Gyr) open cluster NGC 188. Most notably, the model predicts a population of post-CE long-period (~1000 days) circular solar-type main sequence - white dwarf binaries, that are not present in our observations of the true binaries in NGC 188, or any other solar-type binary population in the literature (in star clusters or in the field). The absence of such post-CE systems in real binary populations places important limits on parameters used in most models of CE evolution, and may suggest that more binaries undergo stable mass transfer than has previously been assumed. We discuss how various solutions to this problem would impact other observable stellar populations, including cataclysmic variables, symbiotic stars and blue stragglers.

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133 – HAD V History of Astronomy

Oral Session – Room 12A – Monday, January 9, 2012, 2:00 PM - 3:30 PM

133.01 – **Mapping the Cosmos on a Ceiling: Reflection Sundials from the Seventeenth Century to the Present**

Woodruff T. Sullivan, III[1]

[1]*Univ. of Washington.*
2:00 PM - 2:15 PM

Ceiling reflection sundials employ a small horizontal mirror, say on a south-facing window sill, to cast a spot of sunlight to the ceiling and/or walls of a room or gallery. In this way the linear scale of the daily and annual motions of the sun are greatly amplified, allowing a plethora of information to be displayed and read. Besides the time of day and the date, typical quantities included the altitude and azimuth of the sun, the declination of the sun, the number of hours since sunrise, the length of daylight, the sign of the zodiac, the sidereal time, etc. The principles for planning and calculating these sundials were first laid out in detail in 17th century Italy by the Jesuit scholars Athanasius Kircher and Emmanuel Maignan: two reflection dials of the latter still survive today in Rome, at Trinità dei Monti (1637) and Palazzo Spada (1644). A third extant example can be found at the Lycée Stendhal in Grenoble, built by a Jesuit priest named Bonfa in 1673.

This talk will describe and illustrate these complex sundials, as well as a recently completed ceiling dial, inspired by their example, in the New World (Seattle).

133.02 – **Music and Astronomy: Historical and Contemporary Perspectives**

Matthew Whitehouse[1]

[1]*The University of Arizona.*
2:15 PM - 2:30 PM

The link between music and astronomy has deep historical roots. William Herschel, who is considered to be the father of modern astronomy, began his career as a musician. He was a composer, organist at a church in Bath, UK, and a major contributor to the musical life of that community. Like Herschel, I too am an organist and composer, and much of my creative work focuses on connections between music and astronomy.

This presentation will explore briefly aspects of William Herschel's musical career, and will then focus on contemporary music inspired by astronomical phenomena. Emphasis will be placed on the use of music as a creative teaching tool in informal education environments. The University of Arizona's Astronomy Camp, hosted at both Mt. Lemmon and Kitt Peak National Observatory, will be used as an example and case study. Examples from my creative activity as an organ performer and composer will be

important features of this presentation.

This presentation builds on the session exploring the life and work of the Herschels at the January 2011 AAS Historical Astronomy Division meeting in Seattle, WA.

133.03 – **George William Hill, the Great but Unknown 19th Century Celestial Mechanician**

Brenda G. Corbin[1]

[1]*U.S. Naval Observatory (Retired).*

2:30 PM - 2:45 PM

George William Hill (1838-1914) has long been considered one of the most famous and talented celestial mechanicians of the past century and a half. However, many people have never heard of him and his work. Simon Newcomb said he "…will easily rank as the greatest master of mathematical astronomy during the last quarter of the nineteenth century." After receiving a B.A. at Rutgers in 1859, Hill began work in 1861 at the office of the American Ephemeris and Nautical Almanac in Cambridge, MA. He moved to Washington with the group in 1882 which then became part of the U. S. Naval Observatory. Newcomb, beginning his work on planetary motion, assigned the theory of Jupiter and Saturn to him, calling it about the most difficult topic. Hill's work was published by the USNO in 1890 as *A New Theory of Jupiter and Saturn*. From 1898 to 1901, Hill lectured on the subject of celestial mechanics at Columbia University in a position created just for him. After 1892 and until his death, he lived at the family homestead in West Nyack, NY. He never married, was something of a recluse, and spent most of his time with his books and research. Hill was an amateur botanist and enjoyed exploring on long walks in the countryside. Many honors and awards came to him during his lifetime, both from the U.S. and abroad, including serving as president of the American Mathematical Society. All of Hill's mathematical and astronomical research was incorporated in *The Collected Mathematical Works of George William Hill*. This work, containing a preface in French by Poincare, was published in 4 large volumes by the Carnegie Institution of Washington in 1905.

133.04 – **A Century of Science at the South Pole: From Struggling to Survive to Exploring New and Unseen Frontiers**

Shelly Hynes[1], L. Bacque[2], R. Landsberg[3]

[1]*National Science Foundation Office of Polar Programs,* [2]*IceCube Research Center, University of Wisconsin-Madison,* [3]*Kavli Institute for Cosmological Physics.*

2:45 PM - 3:00 PM

In December of 1911, Norwegian Roald Amundsen and his team became the first to reach the geographic South Pole. Briton Robert F. Scott also reached the South Pole a month later on the 17th of January, 1912. Their successful treks to the South Pole were part of an international rivalry equivalent in its time to the "Space Race" of the 1960's. 100 years later, the National Science Foundation's Amundsen-Scott South Pole Station is home to two massive cutting-edge instruments that are yielding new insights into the Universe at both the smallest and largest scales. The 280-ton, 10-meter South Pole Telescope is probing anisotropies in the cosmic microwave background to understand the nature of Dark Energy and the infant Universe. The IceCube Neutrino Observatory, a cubic kilometer of instrumented ice, searches for evidence of high energy neutrinos that may originate in violent astrophysical events such as supernovae, gamma ray bursts, and active galactic nuclei, as well as help us understand dark matter. The session will highlight education and outreach initiatives associated with both projects.

133.05 – **Astronomers in the Chemist's War**

Virginia L. Trimble[1]

[1]*UC, Irvine.*

3:00 PM - 3:15 PM

World War II, with radar, rockets, and "atomic" bombs was the physicists' war. And many of us know, or think we know, what our more senior colleagues did during it, with Hubble and Hoffleit at Aberdeen; M. Schwarzschild on active duty in Italy; Bondi, Gold, and Hoyle hunkered down in Dunsfeld, Surrey, talking about radar, and perhaps steady state; Greenstein and Henyey designing all-sky cameras; and many astronomers teaching navigation. World War I was The Chemists' War, featuring poison gases, the need to produce liquid fuels from coal on one side of the English Channel and to replace previously-imported dyesstuffs on the other. The talke will focus on what astronomers did and had done to them between 1914 and 1919, from Freundlich (taken prisoner on an eclipse expedition days after the outbreak of hostilities) to Edwin Hubble, returning from France without ever having quite reached the front lines. Other events bore richer fruit (Hale and the National Research Council), but very few of the stories are happy ones. Most of us have neither first nor second hand memories of The Chemists' War, but I had the pleasure of dining with a former Freundlich student a couple of weeks ago.

133.06 – **The Search for Extraterrestrial Intelligence in the 1960s: Science in Popular Culture**

Sierra Smith[1]

[1]*James Madison University.*

3:15 PM - 3:30 PM

Building upon the advancement of technology during the Second World War and the important scientific discoveries which have been made about the structure and components of the universe, scientists, especially in radio astronomy and physics, began seriously addressing the possibility of extraterrestrial intelligence in the 1960s. The Search for Extraterrestrial Intelligence (SETI) quickly became one of the most controversial scientific issues in the post Second World War period. The controversy played out, not only in scientific and technical journals, but in newspapers and in popular literature. Proponents for SETI, including Frank Drake, Carl Sagan, and Philip Morrison, actively used a strategy of engagement with the public by using popular media to lobby for exposure and funding. This paper will examine the use of popular media by scientists interested in SETI to popularize and heighten public awareness and also to examine the effects of popularization on SETI's early development. My research has been generously supported by the National Radio Astronomy Observatory.

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134 – Education Research: Methodologies & Results

Oral Session – Room 18A – Monday, January 9, 2012, 2:00 PM - 3:30 PM

134.01 – **Worldviews: A New Paradigm for Astronomy Education Research**

Colin Scott Wallace[1], E. E. Prather[1], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona.*

2:00 PM - 2:10 PM

Much of astronomy education research focuses on improving students' conceptual understandings of key astronomy topics. But are we missing something important if we restrict our efforts to conceptual change? In this talk, we argue that we also need to shape our instruction such that it affects students' worldviews. By worldview, we mean a set of (often implicit and often non-rational) beliefs, presuppositions, and assumptions about reality that affect our emotions, thoughts, and behaviors, and determine what constitutes valid and important knowledge about the world. Prior science education research has shown that a students' worldview plays a fundamental role in his or her acceptance or rejection of science. We believe that our instruction must be informed by the interplay between students' worldviews and the worldview of science if we want our students to become advocates for science. By advocates for science, we mean they feel motivated and obliged to communicate science to those around them, and they recognize the importance of science for their society, especially as evidenced by the amount of funding they are willing to support for scientific research. This material is based in part upon work supported by the National Science Foundation under Grant Nos. 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.

134.02 – **A Long-Term Study of Science Literacy and Attitudes Towards Science: Exploring Changes Among College Undergraduate and Public Understanding over Twenty-Two Years**

Sanlyn Buxner[1], C. Impey[2], J. Antonellis[3], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Univ. of Arizona,* [2]*Steward Observatory, Univ. of Arizona,* [3]*Little Priest Tribal College.*

2:10 PM - 2:20 PM

Assessing science literacy has been an important goal of science educators and policy makers for many years. Various studies including international, school, and public comparisons have painted a bleak picture of science literacy in the United States. We are conducting a study focused on undergraduates' science literacy using a database of over 10,000 student responses from a large research university collected over a twenty-two year period, between 1989 - 2011. Survey questions were derived from policy driven projects (e.g. NSF Science Indicators), some of which are still used in public assessments of science literacy. Analysis has shown that our university students outperform the public on almost all topics on the survey. Despite targeted university interventions and the rise of public access to knowledge, student science literacy scores have not changed over twenty-two years. Demographic variables explain less than 10% of the variance in students' scores of which the number of university science courses completed is the best predictor. There is a small correlation between students' beliefs in non-scientific phenomenon and lower science literacy scores but students' beliefs about science and technology also explain little variance in their overall scores. We have also compared responses of scientists and students on the same questions about science. We will discuss implications of evaluating students' scientific knowledge in a time when students have access to more resources than ever before, an important goal as we continue to work towards increasing students' understanding of scientific concepts. 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.

134.04D – **Impact of a Backwards Faded Scaffolding (BFS) Approach to Inquiry-Based Astronomy Laboratory Experiences on Undergraduate Non-Science Majors' Views of Scientific Inquiry**

Daniel Jonathan Lyons[1]

[1]*University of Chicago.*

2:30 PM - 2:50 PM

In an effort to support effective instruction in undergraduate astronomy, the Center for Astronomy and Physics Education Research (CAPER) team introduced an inquiry-based laboratory curriculum designed using Backwards Faded Scaffolding (BFS) inquiry teaching framework. A major goal of the curriculum design was to enhance student learning beyond content knowledge alone toward more informed understandings of scientific inquiry through authentic astronomy inquiry experiences using astronomical data sets available online. This study explored the impact of that curriculum on undergraduate non-science majors' views of the nature of scientific inquiry (NOSI).

Over 200 introductory astronomy students' were surveyed using the VOSI-4 questionnaire pre and post intervention. These data were analyzed for significant shifts in understanding of two aspects of NOSI; Distinction Between Data and Evidence (DvE) and Multiple Methods of Science (MMS). These results informed an investigation of lab instructors' observations of students' interactions with the intervention curriculum compared to traditional labs.

Wilcoxon Signed Rank tests showed significant shifts in the distributions of Fall (n=112) and Spring (n=98) samples toward more informed understandings of DvE (Fall, z=-3.811, $p<.00$; Spring, z=-3.698, $p<.001$) , while there was no significant change for understanding of MMS (Fall, z=-.112, p=.910; Spring, z=-.607, p=.544).

Instructor interview analysis suggested that the curriculum provided multiple opportunities for students to evaluate and determine the relevance of data with respect to specific research questions, however they may not have realized they were exclusively engaged in observational rather than experimental inquiries possibly leading students to accommodate their astronomy inquiry experiences within persistent misconceptions of "The Scientific Method" as the only valid method for inquiry.

The results of the study suggest that a purposefully scaffolded, inquiry-based, introductory astronomy laboratory curriculum may be effective in enhancing undergraduate non-science majors' understanding of scientific inquiry and may prove to be a valuable resource for undergraduate astronomy instructors.

134.05 – **Measuring Student Understanding of the Process of Scientific Research through Three Modes of Assessment**

Michelle Krok[1], T. Rector[1], M. J. Young[2]

[1]*University of Alaska Anchorage,* [2]*MJ Young & Associates.*

2:50 PM - 3:00 PM

We have continued to develop "Research-Based Science Education" (RBSE) curriculum and assessment for a semester-long program in which undergraduate non-science majors participate in authentic research. The instruction is mainly astronomy-based, but can be used in any introductory science course. Currently, the curriculum is being used by five universities over an assortment of introductory science and astronomy classrooms. The primary goal of the RBSE curriculum is to develop a student's understanding of the nature and process of scientific research. We will present trends and misconceptions discovered based upon our analysis of Fall 2011 semester student responses to several types of assessments including weekly assigned reflective journal questions on the nature of science and pre/post semester concept maps. Additionally, gains observed from a pre/post semester survey of participatory students' confidence on their science process skills abilities will be discussed.

134.06 – **Epistemological Issues in Astronomy Education Research: How Big of a Sample is "Big Enough"?**

Stephanie Slater[1], T. F. Slater[2], Z. Souri[2]

[1]*CAPER Ctr Phys & Astro Educ Res,* [2]*University of Wyoming.*

3:00 PM - 3:10 PM

As astronomy education research (AER) continues to evolve into a sophisticated enterprise, we must begin to grapple with defining our epistemological parameters. Moreover, as we attempt to make pragmatic use of our findings, we must make a concerted effort to communicate those parameters in a sensible way to the larger astronomical community. One area of much current discussion involves a basic discussion of methodologies, and subsequent sample sizes, that should be considered appropriate for generating knowledge in the field. To address this question, we completed a meta-analysis of nearly 1,000 peer-reviewed studies published in top tier professional journals. Data related to methodologies and sample sizes were collected from "hard science" and "human science" journals to compare the epistemological systems of these two bodies of knowledge. Working back in time from August 2011, the 100 most recent studies reported in each journal were used as a data source: Icarus, ApJ and AJ, NARST, IJSE and SciEd. In addition, data was collected from the 10 most recent AER dissertations, a set of articles determined by the science education community to be the most influential in the field, and the nearly 400 articles used as reference materials for the NRC's Taking Science to School. Analysis indicates these bodies of knowledge have a great deal in common; each relying on a large variety of methodologies, and each building its knowledge through studies that proceed from surprisingly low sample sizes. While both fields publish a small percentage of studies with large sample sizes, the vast majority of top tier publications consist of rich studies of a small number of objects. We conclude that rigor in each field is determined not by a circumscription of methodologies and sample sizes, but by peer judgments that the methods and sample sizes are appropriate to the research question.

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135 – Exciting Astrophysics: Supernovae, Relativistic Astrophysics and Other Results II

Oral Session – Room 16A – Monday, January 9, 2012, 2:00 PM - 3:30 PM

135.01 – **Weak Lensing Tomography with Galaxy Clusters in the SDSS Stripe 82 Coadd**

Melanie Simet[1], J. M. Kubo[2], S. Dodelson[1], J. T. Annis[2], J. Hao[2], D. Johnston[2], H. Lin[2], R. R. R. Reis[3], M. Soares-Santos[2], H. Seo[4]

[1]*The University of Chicago,* [2]*Fermi National Accelerator Laboratory,* [3]*Universidade Federal do Rio de Janeiro, Brazil,* [4]*University of California, Berkeley.*

2:00 PM - 2:10 PM

To achieve good depth and coverage, many future surveys will rely on coadded data, where the same region is observed multiple times and the images combined to increase signal and reduce systematics. We look at weak gravitational lensing around optically-selected galaxy clusters in Stripe 82 of the Sloan Digital Sky Survey, a 270 square degree region of coadded data which is roughly 2 magnitudes deeper than the main SDSS survey. We analyze the stripe in two ways: cluster mass cross-correlation, where we calibrate the relationship between mass and observed richness, and tomography, where we observe that closer galaxies are sheared less than those farther away. The mass-richness relationship we obtain is consistent with other weak lensing results. This confirms that the coaddition process did not degrade the lensing signal. We also parameterize the change in lensing signal with redshift. Using this parameterization, we show that the redshift-distance relationship can be observed, demonstrating that, with further data, weak lensing around clusters can be used to constrain cosmological models.

135.02 – **Strong Field Effects On Emission Line Profiles: Kerr Black Holes And Warped Accretion Disks**

Yan Wang[1], X. Li[2]

[1]*University of Texas at Brownsville,* [2]*Nanjing University, China.*

2:10 PM - 2:20 PM

If an accretion disk around a black hole is illuminated by hard X-rays from non-thermal coronae, fluorescent iron lines will be emitted from the inner region of the accretion disk. The emission line profiles will show a variety of strong field effects, which may be used as a probe of the spin parameter of the black hole and the structure of the accretion disk. In this paper we generalize the previous relativistic line profile models by including both the black hole spinning effects and the non-axisymmetry of warped accretion disks. Our results show different features from the conventional calculations for either a flat disk around a Kerr black hole or a warped disk around a Schwarzschild black hole by presenting, at the same time, multiple peaks, rather long red tails and time variations of line profiles with the precession of the disk. We show disk images as seen by a distant observer, which are distorted by the strong gravity. Although we are primarily concerned with the iron K-shell lines in this paper, the calculation is general and is valid for any emission lines produced from a warped accretion disk around a black hole. This work was supported by the Natural Science Foundation of China (under grant number 10873008), and the National Basic Research Program of China (973 Program 2009CB824800).

135.03 – **A Multi-Messenger Search for Radio Transients and Gravitational Waves**

Michael Kavic[1], J. Simonetti[2], P. Shawhan[3], C. Yancey[3], J. Kanner[3], S. Cutchin[2], S. Ellingson[2]

[1]*Long Island University,* [2]*Virginia Tech,* [3]*University Of Maryland.*

2:20 PM - 2:30 PM

The sensitivity of gravitational waves searches could be improved by coincident observation of electromagnetic signals from expected gravitational wave sources. One possibility is using low-frequency radio transients to trigger and constrain searches for gravitational wave signals. Both are all-sky observations with a number of common sources, and low frequency observations are able to provide spatial and temporal constraints to the search for gravitational wave signals. There is also the added benefit that coincident low-frequency radio and gravitational spectra will allow for more in-depth study of astrophysical events and processes than otherwise possible. In this talk I will layout the case for using low-frequency radio observations to trigger and constrain searches for coincident gravitational wave signals. Common sources and potential ways the joint observation of low-frequency radio and gravitational waves can enhance our understanding of the physics behind these sources will be addressed.

135.04 – **Limitations of Atom Interferometry for Gravitational Wave Observations in Space**

Peter L. Bender[1]

[1]*JILA, Univ. of Colorado and NIST.*
2:30 PM - 2:40 PM

Two main papers have proposed Atomic Gravitational wave Interferometric Sensors (AGIS) in space [1,2]. A Comment on [1] pointed out the strong sensitivity of the proposed AGIS missions to fluctuations in the wavefront aberrations in the laser beams [3]. A Reply to the Comment stated that a high-finesse optical mode-cleaner cavity could be placed after the laser to remove the wavefront aberration fluctuations [4]. However, the proposed AGIS missions require that one of the two laser beams sent in opposite directions between the two atom interferometers at the ends of the path be modulated over quite large frequency ranges on millisecond timescales. This is partly in order to provide large momentum transfer beam splitters and mirrors to separate and recombine different parts of the wave function for the ultra-cold atoms in the atom interferometers. However, since many atom clouds are in the interferometers simultaneously, frequency shifts also are required in order to address the different clouds separately. If a high-finesse mode-cleaner cavity is used for that beam also, varying the transmission frequency of that cavity rapidly enough appears to place a major additional design constraint on the proposed AGIS missions. The extent of this constraint will be discussed briefly in this talk, along with other aspects of the proposed missions.

[1] S. Dimopoulos et al., Phys. Rev. D 78, 122002 (2008)

[2] J. M. Hogan et al., Gen. Relativ. & Gravitation 43, 1953-2009 (2011)

[3] P. L. Bender, Phys. Rev. D 84, 028101 (2011)

[4] S. Dimopoulos et al., Phys. Rev. D 84, 028102 (2011)

135.05 – **The Suitability of Hybrid Waveforms for Advanced Gravitational Wave Detectors**

Ilana MacDonald[1], H. Pfeiffer[1], S. Nissanke[2]

[1]*University of Toronto, Canada,* [2]*California Institute of Technology, Canada.*
2:40 PM - 2:50 PM

General relativity predicts that the coalescence of two compact objects, such as black holes, will produce gravitational radiation; i.e., ripples in the curvature of space-time. Detectors like Advanced LIGO (the Laser Interferometry Gravitational-wave Observatory) are expected to measure such events within the next few years. In order to be able to characterize the gravitational waves they measure, these detectors require accurate waveform models, which can be constructed by fusing an analytical post-Newtonian inspiral waveform with a numerical relativity late-inspiral-merger-ringdown waveform. Numerical relativity, though the most accurate model, is computationally expensive: the longest simulations to date taking several months to run. Post-Newtonian theory, an analytic approximation to General Relativity, is easy to compute but becomes increasingly inaccurate near merger. Because of this trade-off, it is important to determine the optimal length of the numerical waveform, while maintaining the necessary accuracy for gravitational wave detectors. We present a study of the su[[Unsupported Character - ﬃ]]cient accuracy of post-Newtonian and numerical relativity waveforms for the most demanding usage case: parameter estimation of strong sources in advanced gravitational wave detectors. We perform a comprehensive analysis of errors that enter such “hybrid waveforms” in the case of equal-mass non-spinning binaries. Preliminary research has also been done in the case of unequal-mass non-spinning binaries. Accurate hybrids play an important role in investigating the efficiency of gravitational wave search pipelines, as with NINJA (Numerical INJection Analysis); and also in constructing analytical models that span the entire parameter space of binary black hole mass ratios and spins, as with NRAR (Numerical Relativity and Analytic Relativity).

135.06 – **Fermi-lat Measurement Of Cosmic-ray Positron Spectrum Using The Earth's Magnetic Field**

Carmelo Sgro[1], M. Ackermann[2], S. Funk[3], W. Mitthumsiri[3], J. Vandenbroucke[3], Fermi LAT Collaboration

[1]*INFN-Pisa, Italy,* [2]*DESY, Germany,* [3]*SLAC National Accelerator Laboratory.*
2:50 PM - 3:00 PM

With a precise measurement of the combined Cosmic-Ray electron plus positron spectrum, the Fermi Large Area Telescope (LAT) has proven to be an excellent electron detector.

Since the LAT does not have a magnetic field for charge separation, it cannot distinguish electrons from positrons on an event by event basis.

However, we can exploit the Earth's magnetic field to effectively separate negatively and positively charged particles.

With the aid of a precise tabulation of the geomagnetic field, we are able to predict trajectories of particles in this field and use this information to discriminate between positrons and electrons.

We have used this technique for the first time to measure the electron-only spectrum, the positron-only spectrum, and the positron fraction, all between 20 GeV and 200 GeV.

135.07 – **Measuring Agn Black Hole Masses Through X-ray Variability**

Erin Wells Bonning[1], J. Kim[1], C. Urry[1]

[1]*Yale University.*
3:00 PM - 3:10 PM

We discuss the method of estimating black hole masses of AGN (including obscured AGN) using X-ray variability. The normalized excess variance of AGN X-ray light curves has been shown to be proportional to the characteristic break frequency in the power spectral density. This break frequency is tightly correlated with the black hole mass and accretion rate. Therefore, this method is potentially suitable for measuring black hole masses in a homogeneous way, including those for which traditional mass estimates from broad-line widths are unavailable and typically inferred from scaling relations. We present a study of several nearby AGN with known black hole masses and power spectral densities as well as simulated light curves with known power spectra in order to determine the limits of applicability of this method.

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136 – Affordable Large Space Telescopes for UV, Optical, and Exoplanet Astronomy Beyond 2020

Special Session – Room 17B – Monday, January 9, 2012, 2:00 PM - 3:30 PM

The current fiscal climate demands that astronomers examine carefully how emerging technologies can be harnessed to achieve the ASTRO2010 Report's goals for an optical/ultraviolet telescope for the 2020s. In this session, we propose to hear about important developments in telescope technology that could enable a new generation of relatively low cost space telescopes in the 4m to 8m class. The session will include talks from experts in research laboratories and industry focusing on realizable technologies for astronomical space telescopes in the next decade. An associated poster session will provide a glimpse of the many scientific and instrumental possibilities such new telescopes technologies will enable.

136.01 – **Modern Concepts for a Terrestrial Planet Finder Space Telescope**

James Kasting[1]

[1]*Pennsylvania State University.*
2:05 PM - 2:17 PM

Astronomers have now found over 500 exoplanets from radial velocity measurements and another 1200 or more “planet candidates” using the transit method from Kepler. Some of these planets are small enough to be rocky, like Earth, and orbit within the liquid water habitable zone of their parent star. We know next to nothing about conditions on these planets, though, because we have not yet developed the tools needed to study them. Even JWST, if it flies, will likely be unable to characterize the atmosphere of an Earth-analogue exoplanet. What we need for this task is a direct imaging mission that combines a large optical/near-IR telescope with a device that can block out the light from the star and retain the light from a nearby exoplanet. Both internal coronagraphs and external occulters (starshades) are being studied for this purpose. In principle, a thermal-IR telescope operating as an interferometer could accomplish the same task, but this would require formation flying of multiple cooled telescopes and is thought to be a more expensive option. The size of the optical telescope that would be needed to find and characterize an Earth depends on the frequency of Earth-like planet, ηEarth, and the brightness of the average exozodiacal background. The first parameter will hopefully be determined by Kepler, and the second may be measured by the Large Binary Telescope Interferometer, LBTI. Once this information is in hand, and if sufficient money can be found--currently, a big ‘if’--there should be little reason to hold back on designing and launching such a Terrestrial Planet Finder telescope.

136.02 – **Telescopes for Future UV/Optical Astronomy**

Christopher D. Martin[1]

[1]*Caltech.*

2:17 PM - 2:29 PM

Future UV/Optical telescopes will require increasingly large apertures to answer the questions raised by HST, JWST, Planck and Herschel, and to complement the 30-m ground-based telescopes that will be coming on line in the next decade. Large aperture telescopes are required to provide the spatial resolution and sensitivity needed to perform frontier measurements of the future. These include stellar photometry and archaeology of distant galaxies, ultraviolet spectroscopy of the cosmic web, and high resolution imaging that will probe the formation and structure of the first galaxies, the properties of dark matter, and the evolutionary phases of pre-planetary systems. Low-cost, lightweight optics are required to enable the development of such large aperture UV / Optical telescopes in the 2020 decade. Technologies are therefore required that provide a high degree of thermal and dynamic stability, and wave front sensing and control, while minimizing the factors which drive the cost of flagship missions -- complexity, testing challenges, and mass.

136.03 – **New Paradigms for Building An Affordable Large-Aperture UV/Optical Space Telescope**

Matt Mountain[1], J. M. Grunsfeld[1], M. Postman[1]

[1]*STScI.*

2:29 PM - 2:41 PM

The next generation UV/Optical space telescope will be poised to make fundamental scientific breakthroughs if it can achieve resolutions close to an order of magnitude greater than that of HST (and of JWST). Such performance is required for some highly compelling science that will not be readily achieved by any other facility. For example, 10-15 mas spatial resolution and nJy sensitivity are needed if we wish to definitively detect the potentially rare occurrence of biosignatures in the atmospheres of terrestrial-mass exoplanets, to understand the role of supermassive black holes in the formation and evolution of galaxies, and to trace the kinematics of dark matter on galactic scales to directly map the growth of structure over time. If we are to construct such a facility we will need to invest in technologies that allow us to do so at a cost that is comparable with current day large space observatories. This will require new approaches to telescope design.

136.04 – **Driving Requirements for Advanced Space Telescopes**

Martin C. Noecker[1]

[1]*Ball Aerospace & Tech. Corp..*

2:41 PM - 2:53 PM

JWST has blazed a path for segmented deployed space telescopes, enabling larger apertures to be launched than were possible by the principles of the Hubble Space Telescope. Future telescopes for earth science, earth surveillance, and astronomy from space will inherit that experience, but will also face tougher challenges. For earth observing and astronomical telescopes in low earth orbit, we will continue to strive for large collecting area and low mass, aiming to overcome disturbances and achieve stable diffraction limited performance with dramatically lower-mass optics. Some applications, such as exoplanet coronagraphs and transit searches, require extremely stable wavefront knowledge and control, coupled with Hubble-class pointing control. Dark energy studies by the weak lensing method also require a very stable wavefront and body pointing control. Many applications will require advanced control of stray light as well. Thus as these future telescopes get lighter and larger, their performance also must dramatically improve. To achieve stability and accuracy, we are beginning to replace the traditional tools of mass and stiffness with optical measurements in closed loop. This will stretch our thinking about methods of building and testing such telescopes.

136.05 – **Active Optics for Low-Cost Astronomical Space Telescopes**

David Redding[1], D. Coulter[1], J. Wellman[2]

[1]*JPL,* [2]*Applied Optics Xinetics.*

2:53 PM - 3:05 PM

New large, lightweight, replicated, actively controlled primary mirrors offer the potential to reduce the risk and cost of future space telescopes, large and small. For instance, "Actuated Hybrid Mirrors" - with SiC substrates, nanolaminate metal foil reflecting surfaces, and embedded solid-state actuators - have demonstrated the ability to correct many waves of system wavefront error to better than the visible diffraction limit. A space telescope using an active primary, together with occasional wavefront sensing and control, will have relaxed optical system fabrication, integration and test tolerances, making it easier and faster to assemble, and reducing system costs. It will be testable in gravity to the same performance as on orbit. It will be able to correct large errors that can occur during fabrication, assembly, test or launch - reducing mission risk. It will have less primary mirror mass, reducing overall mass in proportion. We consider the implications for future astronomical missions.

136.06 – **SiC for Space Optics**

John Wellman[1]

[1]*Xinetics.*

3:05 PM - 3:17 PM

This paper describes SiC mirrors that are large, ultra-lightweight, and actively controlled, for use in space telescopes. “Advanced Hybrid Mirrors” (AHMs) utilize SiC substrates, with embedded solid-state actuators, bonded to Nanolaminate metal foil reflective surfaces. They use replication techniques for high optical quality as well as rapid, low cost manufacturing. AHMs up to 1.35m in size have been made and tested, demonstrating wavefront error to better than the visible diffraction limit. AHMs can be fabricated at production rates after the first unit delivery as fast as 48 day intervals. “Superpolished Si/SiC Active Mirrors” (SSAMs) are similar to AHMs but the SiC mirror substrates have a layer of Si deposited on them to enable direct superpolishing. SSAMs can be much larger, can operate over a wider temperature range, and are better suited to UV astronomy. To make SSAMs larger than 1.8 m, multiple substrates can be joined together, using brazing techniques. Using wavefront sensing and control technology to command the embedded solid-state actuators, final mirror figure will be set after launch. This gives the active SiC mirror the ability to correct nearly any optical error, occurring anywhere in the optical system. As a result, active SiC mirrors can be made to relaxed figure requirements, enabling optical replication, or speeding up polishing, while assuring excellent final performance. Active SiC mirrors will reduce cost, risk and schedule for future astrophysics missions. Their high control authority allows relaxation of fabrication and assembly tolerances from optical to mechanical levels, speeding I & T. They enable rapid system testing to within required performance levels, even in 1 G, lowering mission risk. They are lighter weight and more durable than glass mirrors.

136.07 – **Cost Effective Space Science Telescopes for Astrophysics Mission in the Upcoming Decades**

Gary Matthews[1]

[1]*ITT Corporation, Space Systems Division.*

3:17 PM - 3:29 PM

Astrophysics programs are dealing with an exciting but challenging dichotomy. On one hand, there has been and will continue to be countless advances in scientific discovery, but on the other the astronomical community is faced with what unfortunately is considered by many to be an insurmountable budgetary impasse for the foreseeable future. The National Academy of Sciences’ Astro2010: Decadal Survey was faced with the difficult challenge of prioritizing sciences and missions for the upcoming decade while still allowing room for new, yet to be discovered opportunities to receive funding. To this end, we propose the consideration of a paradigm shift to the astronomical community that may enable more cost efficient space-based telescope missions to be funded and still provide a high science return per dollar invested. The discussion will provide high level parameters that drive cost and complexity of a telescope system in order to help guide potential PI’s in the early concept development for future missions.

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137 – The Milky Way: Structure of the ISM

Oral Session – Ballroom D – Monday, January 9, 2012, 2:00 PM - 3:30 PM

137.01 – **The Fermi Large Area Telescope View of the Inner Galaxy**

Troy A. Porter[1]

[1]*Stanford University.*

2:00 PM - 2:10 PM

The inner region of the Milky Way galaxy is one of the most interesting and complicated regions of the gamma ray sky because of the many point sources and potential confusion, the uncertainties associated with the diffuse gamma-ray emission, together with the potential for dark matter detection. In this talk, we report on the Fermi LAT team analysis of the region around the direction of the galactic center using over 2 years of data.

137.02D – **The Discovery of Fermi Bubbles: Multi-wavelength Observations and Implications to the Past Activity of Galactic Center**

Meng Su[1]

[1]*Harvard University.*

2:10 PM - 2:30 PM

Data from the Fermi-LAT reveal two large gamma-ray bubbles, extending 50 degrees above and below the Galactic center, with a width of about 40 degrees in longitude. The gamma-ray emission associated with these bubbles has a significantly harder spectrum ($dN/dE \sim E^{-2}$) than the IC emission from electrons in the Galactic disk, or the gamma-rays produced by decay of pions from proton-ISM collisions. The bubbles are spatially correlated with the hard-spectrum microwave excess known as the WMAP

haze; the edges of the bubbles also line up with features in the ROSAT X-ray maps at 1.5 – 2 keV. We further discovered arge cocoon structures in Fermi gamma-ray data, which is presumably produced by relativistic large scale jets. I will summarize observational evidence of the Fermi bubbles and cocoons, including features of polarization and rotation measure of the bubble edges. The bubbles have sharp edges in gamma-ray, X-ray, and polarized microwave emission. I'm going to argue that these Galactic gamma-ray bubbles are ongoing shocks (instead of a stable structure), and were most likely created by some large episode of energy injection in the Galactic center, such as past accretion events onto the central massive black hole, or a nuclear starburst in the last ~10 Myr.

137.03D – **The Milky Way's Most Luminous Star Clusters: Engines of Galaxy Evolution**

Mubdi Rahman[1], C. D. Matzner[1], D. Moon[1]

[1]*University of Toronto, Canada.*
2:30 PM - 2:50 PM

Massive young star clusters and OB associations ($M > 10^4$ M_{sun}) dominate the energetic feedback from stars into the interstellar medium. They contain the most massive and luminous stars in the Galaxy, which shape their environments through winds, ionizing flux, radiation pressure, and eventually supernovae, destroying their natal molecular clouds and inflating superbubbles. Few such clusters have been identified in our Galaxy. We systematically investigate the most luminous H II regions, which we identify using the WMAP foreground maps. We find that the 13 most luminous sources produce one-third of the Galaxy's total ionizing luminosity, all with expected powering populations of $M > 4\times10^4$ M_{sun}. These populations are grouped in small numbers of clusters or associations for each WMAP source. The emission from these regions is dominated by the diffuse component at large radii (~10-70 pc) indicating a high leaking fraction of ionizing photons. Using 8 micron maps from Spitzer GLIMPSE and published radio recombination line observations, we resolve the large (>1°) WMAP sources into 40 star forming complexes (SFCs) exhibiting shell morphology with evidence of expansion due to a central powering source. We develop a method, based on differential extinction of the galactic disk, to identify the SFC's powering cluster candidates with 2MASS. We identify 25 candidate clusters within the 40 SFCs having extinctions consistent with their distances. With near-infrared spectroscopy from the New Technology Telescope, we have confirmed the existence of the most massive of these associations, the Dragonfish Association, with $M = 10^5$ M_{sun}. Of the 50 sampled stars, we identify 2 Luminous Blue Variable candidates, a Wolf-Rayet, and 15 O-type stars, consistent with the yield expected from the candidate contamination rate, verifying the candidate cluster identification method. This investigation produces the most complete picture of the upper-end of the Galaxy's cluster mass function to date.

137.04D – **Infrared Extinction and Stellar Populations in the Milky Way Midplane**

Gail Zasowski[1], S. R. Majewski[1], R. A. Benjamin[2], D. L. Nidever[1], M. F. Skrutskie[1], R. Indebetouw[1], R. J. Patterson[1], M. R. Meade[3], B. A. Whitney[3], B. Babler[3], E. Churchwell[3], C. Watson[4]

[1]*University of Virginia,* [2]*University of Wisconsin-Whitewater,* [3]*University of Wisconsin,* [4]*Manchester College.*
2:50 PM - 3:10 PM

The primary laboratory for developing and testing models of galaxy formation, structure, and evolution is our own Milky Way, the closest large galaxy and the only one in which we can resolve large numbers of individual stars. The recent availability of extensive stellar surveys, particularly infrared ones, has enabled precise, contiguous measurement of large-scale Galactic properties, a major improvement over inferences based on selected, but scattered, sightlines. However, our ability to fully exploit the Milky Way as a galactic laboratory is severely hampered by the fact that its midplane and central bulge -- where most of the Galactic stellar mass lies -- is heavily obscured by interstellar dust. Therefore, proper consideration of the interstellar extinction is crucial. This thesis describes a new extinction-correction method (the RJCE method) that measures the foreground extinction towards each star and, in many cases, enables recovery of its intrinsic stellar type. We have demonstrated the RJCE Method's validity and used it to produce new, reliable extinction maps of the heavily-reddened Galactic midplane. Taking advantage of the recovered stellar type information, we have generated maps probing the extinction at different heliocentric distances, thus yielding information on the elusive three-dimensional distribution of the interstellar dust. We also performed a study of the interstellar extinction law itself which revealed variations previously undetected in the diffuse ISM and established constraints on models of ISM grain formation and evolution. Furthermore, we undertook a study of large-scale stellar structure in the inner Galaxy -- the bar(s), bulge(s), and inner spiral arms. We used observed and extinction-corrected infrared photometry to map the coherent stellar features in these heavily-obscured parts of the Galaxy, placing constraints on models of the central stellar mass distribution.

137.05D – **Magnetic Fields in the Milky Way Probed with NIR Polarimetry**

Michael D. Pavel[1]

[1]*Boston University.*
3:10 PM - 3:30 PM

The source of the Galactic magnetic field and the role it plays in the energy budget and evolution of the ISM is poorly understood. What sustains Galactic magnetic fields on Gyr timescales? How do these magnetic fields affect the evolution of the ISM? Are magnetic fields critical to setting up the conditions for star formation to begin? In my dissertation, I address these questions by measuring the properties of magnetic fields in the Milky Way and, for comparison, M51 with NIR starlight polarimetry. NIR starlight polarimetry traces the orientation of magnetic fields, in the plane of the sky, via aligned dust. I have generated all-sky starlight polarization predictions for a variety of Galactic magnetic field geometries. Combining these with new NIR polarimetry, I am able place constraints on the large-scale geometry of the Galactic magnetic field, and therefore the mechanism that generates that field. The spiral-type magnetic pitch angle is also measured in the outer Galaxy. For comparison, the face-on spiral galaxy M51 has been mapped with resolved NIR polarimetry. The magnetic differences between M51 and our Galaxy and their implications for dynamo-generated, large-scale magnetic fields are discussed. On smaller scales in the Milky Way, NIR polarimetry of individual infrared dark clouds and Galactic bubbles is shown. Combined with knowledge of the gas properties from 13CO radio data, magnetic field strengths can be estimated using the Chandrasekhar-Fermi method. This also allows me to compare magnetic pressure to other forces acting in these environments. The implications for the energy budget of the ISM and the effect magnetic fields have on the evolution of these objects are discussed.

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138 – The Challenges and Achievements in 50 Years of Human Spaceflight

Invited Session – Ballroom D – Monday, January 9, 2012, 3:40 PM - 4:30 PM

138.01 – **The Challenges and Achievements in 50 Years of Human Spaceflight**

Steven A. Hawley[1]

[1]*University of Kansas.*
3:40 PM - 4:30 PM

On April 12, 1961 the era of human spaceflight began with the orbital flight of Cosmonaut Yuri Gagarin. On May 5, 1961 The United States responded with the launch of Alan Shepard aboard Freedom 7 on the first flight of Project Mercury. The focus of the first 20 years of human spaceflight was developing the fundamental operational capabilities and technologies required for a human mission to the Moon. The Mercury and Gemini Projects demonstrated launch and entry guidance, on-orbit navigation, rendezvous, extravehicular activity, and flight durations equivalent to a round-trip to the Moon. Heroes of this epoch included flight directors Chris Kraft, Gene Kranz, and Glynn Lunney along with astronauts like John Young, Jim Lovell, Tom Stafford, and Neil Armstrong. The "Race to the Moon" was eventually won by the United States with the landing of Apollo 11 on July 20, 1969. The Apollo program was truncated at 11 missions and a new system, the Space Shuttle, was developed which became the focus of the subsequent 30 years. Although never able to meet the flight rate or cost promises made in the 1970s, the Shuttle nevertheless left a remarkable legacy of accomplishment. The Shuttle made possible the launch and servicing of the Hubble Space Telescope and diverse activities such as life science research and classified national security missions. The Shuttle launched more than half the mass ever put into orbit and its heavy-lift capability and large payload bay enabled the on-orbit construction of the International Space Station. The Shuttle also made possible spaceflight careers for scientists who were not military test pilots - people like me. In this talk I will review the early years of spaceflight and share my experiences, including two missions with HST, from the perspective of a five-time flown astronaut and a senior flight operations manager.

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139 – HAD Doggett Prize: Cosmic Noise: The Pioneers of Early Radio Astronomy and Their Discoveries

Invited Session – Ballroom D – Monday, January 9, 2012, 4:30 PM - 5:20 PM

139.01 – **Cosmic Noise: The Pioneers of Early Radio Astronomy and Their Discoveries**

Woodruff T. Sullivan, III[1]

[1]*Univ. of Washington.*

Extraterrestrial radio waves (the galactic background), often referred to as "cosmic noise", were first detected accidentally by Karl Jansky at a frequency of 20 MHz in

1932, with significant followup by Grote Reber. Yet after World War II it was England and Australia that dominated the field. An entirely different sky from that of visual astronomy was revealed by the discoveries of solar noise, “radio stars” (discrete sources such as Cas A, Tau A, Cyg A, Cen A and Vir A), galactic noise, lunar and meteor radar experiments, the detection of the 21 cm hydrogen line, and eventually optical identifications such as the Crab Nebula and M87. Key players included wartime radar experts such as Stanley Hey (the British Army's Operational Research Group), Martin Ryle (Cambridge University), Bernard Lovell (Jodrell Bank) and Joe Pawsey (Radiophysics Lab, Sydney). Younger leaders also emerged such as Graham Smith, Tony Hewish, John Davies, "Chris" Christiansen, Bernie Mills, Paul Wild, and John Bolton. Some optical astronomers (Jan Oort, Henk van de Hulst, Jesse Greenstein, Rudolph Minkowski, and Walter Baade) were also extremely supportive. By the end of the postwar decade, radio astronomy was firmly established within the gamut of astronomy, although very few of its practitioners had been trained as astronomers.

I will also trace the technical and social aspects of this wholly new type of astronomy, with special attention on military and national influences. I argue that radio astronomy represents one of the key developments in twentieth century astronomy not only because of its own discoveries, but also its pathfinding for the further opening the electromagnetic spectrum.

This study is based on exhaustive archival research and over one hundred interviews with pioneering radio astronomers. Full details are available in the book "Cosmic Noise: A History of Early Radio Astronomy" (Cambridge Univ. Pr.).

200 – HEAD Rossi Prize: Science with the Fermi LAT

Invited Session – Ballroom D – Tuesday, January 10, 2012, 8:30 AM - 9:20 AM

200.01 – **The Fermi Large Area Telescope at 3 Years: A Summary of What Has Been Learned About the High-Energy Sky**

Peter F. Michelson[1]

[1]*Stanford University.*

The Fermi Gamma-ray Space Telescope was launched on June 11, 2008; within days of full activation, the first Large Area Telescope (LAT) all-sky map of the sky revealed new high-energy sources and since the start of science operations in August 2008, the LAT has been observing the entire sky once every three hours. These observations have revealed more than 1,873 high-energy gamma-ray sources, including several classes of active galaxies, pulsars, pulsar wind nebulae, supernova remnants, binary sources, high-energy gamma-ray bursts, a nova, the Sun and most recently Terrestrial Gamma Ray Flashes. The data has revealed not only new sources and source classes, but has taught us unexpected new things about known sources such as the Crab nebula. This talk begins with a brief reminiscence of how Fermi (then known as GLAST) was conceived of, then reviews the science return for the first 3 years, and concludes with a summary of questions about the high-energy sky and other areas of astronomy and physics that remain to be answered and that future observations with the Fermi Observatory can address.

200.02 – **The Fermi Large Area Telescope: Optimizing and Then Re-Optimizing the Science Return**

W. B. Atwood[1]

[1]*UCSC.*

The general concepts of how to do gamma-ray observations in space were well established and vetted by the early 1990’s. In particular, the success of EGRET onboard the Compton Gamma Ray Observatory whetted the appetite for a more ambitious follow on. In parallel, advances in high-energy particle detection, spurred on by plans for the Superconducting Super Collider, provided an unprecedented opportunity for space-based detectors. The GLAST concept, now Fermi-LAT, was born at SLAC in May of 1992 and the instrument was subsequently developed by an international collaboration from France, Italy, Japan, Sweden and the United States. An overview of the original design optimization of the LAT instrument, done with the goal of imposing as few limits as possible on its applications in space, is discussed (along with some of the trials and tribulations of construction along the way to launch!). Now with over 3 years of science operations experience, the lessons-learned will be reviewed and assessed against the expectations. Finally, the ongoing re-optimization of the instrument and plans for how to extend the LAT’s science window into the future are discussed.

235 – Education Research: Methodologies & Results

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

235.01 – **First Step in Building an Astronomy Learning Progression: Analyzing Student Conceptions of Astronomical Phenomena**

Christopher Palma[1], J. Petula[1], J. Plummer[1], A. Flarend[1], G. Goldsborough[2]

[1]*Penn State Univ.,* [2]*Pennsbury School District.*

9:00 AM - 6:30 PM

The Earth and Space Science Partnership (ESSP) collaborated with Pennsylvania teachers to research how grades 4-9 students learned selected topics in Earth and Space Science. Prior to a professional development workshop in astronomy, held during the summer of 2011 at the Pennsylvania State University, 15 participating teachers gave their students a pilot astronomy assessment with questions on the Sun-Earth-Moon system, scale of the Solar System, phases of the Moon, perspective view of the celestial sphere, and planetary orbital velocities. Analysis of students' work revealed cross-cutting themes: patterns, scale, position and relations, time, and motion in the context of these solar system phenomena. Further analysis of students' responses may facilitate the development of an empirical "learning progression" that reveals the pathways students follow as they progress from novice to expert understanding of the underlying astronomical phenomena (e.g., lunar phases) related to these questions.

This poster presents initial analysis, data, and findings based on the student work obtained during the summer of 2011. During subsequent project years, the assessment will be iteratively refined and distributed to additional students in our partner school districts, and this large database of student responses will be used to refine the learning progression. We expect also to use these student work samples to produce a set of performance standards that teachers can use to evaluate the location of students progression from novice to expert understanding of essential astronomical phenomena.

We gratefully acknowledge support from the NSF from a Targeted Math Science Partnership award DUE#0962792.

235.02 – **Two Eyes, 3D: A New Project to Study Stereoscopy in Astronomy Education**

Aaron Price[1], M. SubbaRao[2], R. Wyatt[3]

[1]*AAVSO,* [2]*Adler Planetarium and Astronomy Museum,* [3]*California Academy of Sciences.*

9:00 AM - 6:30 PM

"Two Eyes, 3D" is a 3-year NSF funded research project to study the educational impacts of using stereoscopic representations in informal settings. The project funds two experimental studies. The first is focused on how children perceive various spatial qualities of scientific objects displayed in static 2D and 3D formats. The second is focused on how adults perceive various spatial qualities of scientific objects and processes displayed in 2D and 3D movie formats. As part of the project, two brief high-definition films about variable stars will be developed. Both studies will be mixed-method and look at prior spatial ability and other demographic variables as covariates. The project is run by the American Association of Variable Star Observers, Boston Museum of Science and the Adler Planetarium and Astronomy Museum with consulting from the California Academy of Sciences. Early pilot results will be presented. All films will be released into the public domain, as will the assessment software designed to run on tablet computers (iOS or Android).

235.03 – **Assessing Student Learning in the Planetarium**

Paul Sell[1], E. J. Hooper[1]

[1]*The University of Wisconsin-Madison.*

9:00 AM - 6:30 PM

For decades, the effectiveness of the planetarium as a teaching tool has been investigated without a clear answer. As teaching paradigms have shifted, the usefulness and roles of planetaria must be made clearer if instructors are to make the best use of this expensive and unique tool. We have taught one week of discussion sections in each of the three Astronomy 103 classes at the University of Wisconsin-Madison using permutations of PowerPoint presentations and instructor- and student-centered demonstrations in the classroom or planetarium with the same learning goals. Our central research question: how does student learning of basic celestial motions in an introductory astronomy classroom depend on various teaching methods and tools incorporated with, or instead of, a planetarium presentation. The effectiveness of varied approaches was tested by giving students pre- and post-tests to gauge what they learned from the our planetarium or classroom discussions and demonstrations.

235.04 – **Insights Into Students’ Interests by Examining Their Choices of the Astronomy Picture of the Day**

Windsor A. Morgan, Jr.[1]

[1]*Dickinson College.*

9:00 AM - 6:30 PM

Knowing the interests of undergraduates in introductory astronomy courses can help make a more engaging course for the students. Over several years students at Dickinson have been asked to choose a recent (within the previous two or three years) Astronomy Picture of the Day (APOD) to present to their classmates. The Picture can

be of anything they choose, and does not have to be related to the areas covered in the astronomy course.

I divide the student-presented Pictures into broad topics, and compare those choices to the population of Pictures that was available at the APOD website. The choices of the students, compared to what Pictures were available, give insight into what appeals to them. In addition, I discuss the popularity of APOD Picture topics offered at the website over the last ten years as well as student reasons for picking the picture that they did.

235.05 – **Lunatics in Introductory Physics: Using Collectivized Student Moon Position Observations To Teach Basic Orbital Mechanics In Calculus Based Introductory Physics.**

Mark Bottorff[1]

[1]*Southwestern Univ.*.

9:00 AM - 6:30 PM

A large (74 student) calculus based physics class was required to make observations of the moon over two lunar cycles using a small telescope equipped with mechanical setting circles. The data was collectivized and then analyzed in the laboratory to determine the period of the moon and to search for evidence of the eccentricity of the moon's orbit. These results were used in conjunction with the simple pendulum experiment in which the students inferred the acceleration due to gravity. The student inferred lunar orbital period and acceleration due to gravity (augmented with the radius of the Earth) enabled the students to infer the average Earth to moon distance. Class lectures, activities, and homework on gravitation and orbits were tailored to this observational activity thereby forming a learning module. A basic physics and orbital mechanics knowledge questionnaire was administered before and after the learning module. The resulting learning gains are reported here.

235.07 – **Involving High School Students in Astronomy Research: What's the goal?**

Sue Ann Heatherly[1], S. Scoles[1], M. McLaughlin[2], D. Lorimer[2]

[1]*NRAO,* [2]*WVU.*

9:00 AM - 6:30 PM

The Pulsar Search Collaboratory (PSC) is an NSF funded ITEST program that engages high school students and their teachers in radio astronomy research. Teachers and students from 72 schools have received training through this program. More than 300 students have joined with astronomers in analyzing data, and several discoveries have been made. In this paper we examine the evaluation data collected to determine if initial goals were met, and if in fact, the initial goals were the right ones. In particular we examine whether participation in the PSC a) affected students' and teachers' understanding of the nature of scientific inquiry, and b) motivated students to pursue STEM career paths.

235.08 – Digital Devices, Distraction and Student Performance - Does Cell Phone Use Reduce Learning?

Douglas K. Duncan[1], A. R. Hoekstra[1], B. R. Wilcox[1]

[1]*Univ. of Colorado.*

9:00 AM - 6:30 PM

The recent increase in the use of digital devices such as laptop computers, iPads and web-enabled cell phones has generated concern about how technologies affect student performance. Combining observation, survey, and interview data, this research assesses the effects of technology use for student attitudes and learning. Data were gathered in eight introductory science courses at one large public university in 2010-2011. Results show a significant negative correlation between in-class cell phone use and overall course grades, corresponding to a drop of 0.36 ± 0.08 on a 4-point scale where 4.0 = A. These findings are consistent with recent research[1] suggesting students cannot multi-task nearly as effectively as they think they can. While 75% of students reported regular cell phone use, observation data suggests undergraduates typically under-report the frequency of in-class digital device use.

[1] Ophir, E., Nass, C. and A.D. Wagner. 2009. "Cognitive Control in Media Multi-Taskers." Proceedings of the National Academy of Sciences, 106: 15583-15587.

236 – Professional Development for Students & Teachers

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

236.01 – **Professional Development Workshops for K-8 Teachers: Workshops in Science Education and Resources (Project WISER)**

Larry A. Lebofsky[1], A. M. Baldridge[1], L. F. Bleamaster[1], S. R. Buxner[1], T. L. Canizo[1], S. K. Croft[1], D. A. Crown[1], S. J. Kortenkamp[1], A. Yingst[1], E. Pierazzo[2]

[1]*Planetary Science Institute,* [2]*Planetary Science Institute, Deceased.*

9:00 AM - 6:30 PM

The Planetary Science Institute, in partnership with the Tucson Regional Science Center, offers a series of professional development workshops targeting elementary and middle school teachers in Tucson, Arizona. Using NASA data sets, research results, and a team of Earth and space scientists and educators, these workshops provide teachers with in-depth content knowledge of fundamental concepts in astronomy, geology, and planetary science. By participating in hands-on exercises, the teachers model the processes and skills scientists use. With a stronger knowledge of science content and of how science is actually conducted, the workshops instill greater confidence in teachers' ability to teach earth and space science. Currently 72 teachers from 39 schools have attended 14 offerings of our workshops. One measure of success of our program is that over 50% of teachers have attended two to five of our workshops. Teachers consistently cite hands-on activities, modeling of scientific process, and interaction with scientists as the three top benefits of the workshops. Additionally, they report an increase in the knowledge of science content, increased understanding of how science is actually conducted and a greater confidence in their ability to teach earth and space science. Current workshops are: *Moon-Earth System, Exploring the Terrestrial Planets, Impact Cratering, Asteroid-Meteorite Connection,* and *Volcanoes of the Solar System.* Two more workshops, *Deserts of the Solar System and Astrobiology* and *the Search for Extrasolar Planetary Systems* are being developed. A successful component of our program has been the use of rock and meteorite kits as an integral part of our instruction. In addition, we are now developing a series of short workshops to train educators to learn to use the kits in their classrooms, science fairs, star parties, and other educational and social events. Details of our workshops can be found at: www.psi.edu/epo/pdworkshops.

236.02 – **Teacher Professional Development with SOFIA from Inception to Flight**

Mary Kay Hemenway[1], J. Lacy[1], C. Sneden[1], SOFIA EXES Teacher Associates

[1]*Univ. of Texas at Austin.*

9:00 AM - 6:30 PM

Since January 1998 Texas science and math teachers have met several times per year in a program centered on SOFIA, the Stratospheric Observatory for Infrared Astronomy. Initial meetings focused on astronomical instrumentation as the ground-based TEXES (Texas Echelon Cross Echelle Spectrograph) and its SOFIA successor, EXES, were developed and built. Sixty-nine different teachers have been involved in the seventy-nine Saturday meetings between January 1998 and October 2011. A typical meeting included an update on SOFIA, an expert talk on a science or technology topic, and a Standards-linked activity that they can carry back to use in their classrooms. Many of the participants have presented activities or reports to their colleagues. A variety of guest-presenters - faculty, staff, and graduate students as well as visitors (both in person and through videoconference) - enriched the program with their expertise. Some Saturday meetings included field trips to Waco to visit the SOFIA aircraft modification; other trips sent subsets of teachers to McDonald Observatory for TEXES' early observations, to Hawaii for observing runs on the IRTF or Gemini, and to various locations for American Astronomical Society meetings. The participants report their increased knowledge of astronomical concepts and of the culture of professional astronomy. By spreading the SOFIA EXES teacher program over such a long period, the staff has formed strong professional bonds with the participants while the participants have shared their experiences with each other.

Support from USRA grant 8500-98-008; the National Science Foundation AST-0607312, AST- 0607708, and AST-0908978; and SOFIA Education/Public Outreach through the SETI Institute 08-SC-1022 is gratefully acknowledged.

236.03 – **Year 4 Of The NSF-funded PAARE Project At SC State**

Donald K. Walter[1], S. D. Brittain[2], J. L. Cash[1], D. H. Hartmann[2], S. B. Howell[3], J. R. King[2], M. D. Leising[2], E. A. Mayo[1], K. J. Mighell[4], D. M. Smith[1]

[1]*South Carolina State University,* [2]*Clemson University,* [3]*NASA Ames Research Center,* [4]*National Optical Astronomy Observatory.*

9:00 AM - 6:30 PM

We summarize the progress made through Year 4 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. Fellowships provided by POCA as well as recruitment efforts on the national level have resulted in enrolling a total of four underrepresented minorities into the Ph.D. program in astronomy at Clemson. We report on the success and challenges to recruiting students into the undergraduate physics major with astronomy option at SC State. Our summer REU program under POCA includes underrepresented students from across the country conducting research at each of our three institutions. Examples are given of our inquiry-based, laboratory exercises and web- based activities related to cosmology that have been developed with PAARE funding. We discuss our ground-based photometric and spectroscopic study of RV Tauri

and Semi-Regular variables which has been expanded to include successful Cycle 2 Kepler observations of a dozen of these objects reported elsewhere at this conference (see D.K. Walter, et.al.). 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 award NNX11AB82G.

236.04 – **The Lowell Observatory Predoctoral Scholar Program**

Jeffrey C. Hall[1], L. A. Prato[1]

[1]*Lowell Obs..*

9:00 AM - 6:30 PM

Lowell Observatory is pleased to solicit applications for our Predoctoral Scholar Fellowship Program. Now beginning its fifth year, this program provides unique research opportunities to graduate students in good standing and 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, and stellar populations and dwarf irregular galaxies.

The Observatory's new 4.3-meter Discovery Channel Telescope is on track for first light by mid-2012, making this a particularly exciting time in our history. Student research is expected to lead to a thesis dissertation appropriate for graduation at the doctoral level at the student's home institution.

Currently, three students are enrolled and three have successfully completed their thesis work at Lowell and moved on to postdocs and astronomy jobs elsewhere. 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 2012 are due by May 1, 2012.

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237 – Pulsars, Neutron Stars

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

237.01 – **An Enhanced Analytical Model for Thermal and Bulk Comptonization in Accretion-powered X-ray Pulsars**

Peter A. Becker[1]

[1]*George Mason University.*

9:00 AM - 6:30 PM

A new analytical model describing spectral formation in accretion-powered X-ray pulsars is presented. The new model expands on previous work published by the authors by utilizing an improved column geometry combined with a more realistic variation for the accretion velocity. The velocity in the new model approaches the local Newtonian free-fall velocity far above the star, and the accretion column has a conical geometry, which is a reasonable approximation to the magnetic dipole in an X-ray pulsar. The transport equation includes bulk and thermal Comptonization, and the spectral solution for the Green's function is obtained using a mathematically rigorous eigenfunction expansion method. The method includes the application of realistic boundary conditions at the stellar surface and also at a large altitude above the star. The spectrum of the radiation escaping through the column walls is computed by convolving the Green's function with bremsstrahlung, cyclotron, and blackbody source terms. The emergent spectrum displays a relatively flat continuum shape with a high-energy quasi-exponential cutoff, in agreement with the observations of the luminous pulsars Her X-1, LMC X-4, and Cen X-3. We show that the observed spectrum is dominated by Comptonized bremsstrahlung emission in these sources.

237.02 – **The X-ray Counterpart Of The High-*B* Pulsar PSR J0726-2612**

Josh Speagle[1], D. L. Kaplan[1], M. H. van Kerkwijk[2]

[1]*UW-Milwaukee,* [2]*University of Toronto, Canada.*

9:00 AM - 6:30 PM

Middle-aged, cooling neutron stars are observed both as relatively rapidly spinning radio pulsars and as more slowly spinning, strongly magnetized isolated neutron stars (INSs), which stand out by their thermal X-ray spectra. The difference between the two classes may be that the INSs initially had much strong magnetic fields that have decayed. In order to test this, we used the *Chandra X-ray Observatory* to observe 1RXS J072559.8-261229, a possible X-ray counterpart to PSR J0726-2612, the nearest and least extincted among the possible slowly-spinning, strong-field INS progenitors with a 3.44 s period and an inferred magnetic field of 3×10^{13} G (it is likely in the Gould belt, at ~1 kpc). We confirm the identification and find that the pulsar has a spectrum consistent with being purely thermal, with a blackbody temperature $kT = 87\pm5$ eV and radius $R \sim 5.7$ km kpc^{-1}. We also detect sinusoidal pulsations at twice the radio period with a semi-amplitude of 27±5%. The properties of PSR J0726-2612 strongly resemble those of the INSs, except for its much shorter characteristic age of 200 kyr (rather than several Myr). We conclude that PSR J0726-2612 is indeed an example of a young INS - one that started with a magnetic field strength on the low end of those inferred for the INSs and, therefore, has decayed by a relatively small amount. Our results suggest that long-period, strong-field pulsars and INSs are members of the same class. Our identification also opens up new opportunities to understand the puzzling X-ray and optical emission of the INSs, since radio timing, polarimetry, and astrometry can all better constrain the distance, age, phase stability, and emitting geometry of PSR J0726-2612 than would be possible with X-ray data alone.

237.03 – **Near IR Astrometry Of Magnetars**

Shriharsh P. Tendulkar[1], P. B. Cameron[1], S. R. Kulkarni[1]

[1]*California Institute of Technology.*

9:00 AM - 6:30 PM

We present precise astrometric measurements of 5 magnetars gathered over a five year baseline to understand the motion and origin of these objects.

The origin of large magnetic fields (B ~ 10^{14} - 10^{15} G) in magnetars and the relation between magnetars and the general population of neutrons stars is not well known. Simulations have suggested that the strong magnetic fields in the cores of the progenitor stars would create asymmetries in neutrino emission, leading to higher space velocities (~ 1000 km/sec) for this population as compared to `normal' neutron stars (~ 200 - 300 km/sec). The direction of motion of these objects can help identify the possible origin (a supernova remnant or a massive-star cluster) which can place constraints on their age and distance.

We used the laser guide star adaptive optics equipped NIRC2 camera on the 10-m Keck telescope to image the target fields with high-resolution in K band. Preliminary results show that magnetars are young objects and do not have kinematics distinct from the general neutron star population.

237.04 – **Observational Constraints on Radio Transient Emissions from Binary Neutron Star Mergers**

Joanna Papadopoulos[1], D. Dispoto[1], B. Cardena[1], M. Kavic[2], S. Ellingson[3], J. Simonetti[3], S. Cutchin[3], C. Patterson[3]

[1]*The College of New Jersey,* [2]*Long Island University,* [3]*Virginia Tech.*

9:00 AM - 6:30 PM

The merger of a binary neutron star pair is expected to generate a strong transient radio signal. This emission will be strongest at low-frequency 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 Eight-meter-wavelength Transient Array (ETA) telescope is a low-frequency radio telescope initially located at the Pisgah Astronomical Research Institute (PARI), which is sensitive to a frequency range of 29-47 MHz. It is being upgraded and relocated to western Virginia where it will continue to conduct low frequency observations. This instrument is an all-sky instrument designed to detect astronomical sources of radio transients. Using a series of observations taken during the ETA's first science run, we were able to constrain the rate of such merger events to $<1.3 \times 10^{-5}$ Mpc^{-3}/yr.

237.05 – **Speeding Up Blind Gamma-Ray Pulsar Searches with GPUs**

Ethan Kruse[1], S. Ransom[2]

[1]*Harvard University,* [2]*NRAO.*

9:00 AM - 6:30 PM

We present results on the feasibility of a blind search for isolated and binary pulsars using Fermi. A blind search with Fermi data provides essentially uniform coverage of the whole sky, yielding unbiased pulsar samples for further radio followup and population analyses.

We implemented a highly optimized GPU-based phase-modulation search to greatly accelerate (by almost 50 times) blind searches for isolated gamma-ray pulsars. Even at its most efficient, a complete search over one gamma-ray source would take on the order of a few days -- expensive, but feasible utilizing a GPU cluster.

Finally, we used the optimized algorithm to search for gamma-ray pulsars in simulated data to test its detection limits. For photon-based searches we determined that roughly 4000 or more photons are required for the phase-modulation search to detect a typical MSP in 3 years of data. Unfortunately this is brighter than any of the Fermi unassociated sources likely to be pulsars.

237.06 – **Population Synthesis of Radio and Gamma-ray Pulsars using the Maximum Likelihood Approach**

Caleb Billman[1], P. L. Gonthier[1], A. K. Harding[2]

[1]*Hope College,* [2]*NASA Goddard Space Flight Center.*

9:00 AM - 6:30 PM

We present the results of a pulsar population synthesis of normal pulsars from the

Galactic disk using a maximum likelihood method. We seek to maximize the likelihood of a set of parameters in a Monte Carlo population statistics code to better understand their uncertainties and the confidence region of the model's parameter space. The maximum likelihood method allows for the use of more applicable Poisson statistics in the comparison of distributions of small numbers of detected gamma-ray and radio pulsars. Our code simulates pulsars at birth using Monte Carlo techniques and evolves them to the present assuming initial spatial, kick velocity, magnetic field, and period distributions. Pulsars are spun down to the present and given radio and gamma-ray emission characteristics. We select measured distributions of radio pulsars from the Parkes Multibeam survey and Fermi gamma-ray pulsars to perform a likelihood analysis of the assumed model parameters such as initial period and magnetic field, and radio luminosity. We present the results of a grid search of the parameter space as well as a search for the maximum likelihood using a Markov Chain Monte Carlo method.

We express our gratitude for the generous support of the Michigan Space Grant Consortium, of the National Science Foundation (REU and RUI), the NASA Astrophysics Theory and Fundamental Program and the NASA Fermi Guest Investigator Program.

237.07 – **Pulsar Search Results from the Arecibo Remote Command Center**

Kevin Stovall[1], F. A. Jenet[2], X. Siemens[3], A. J. Ford[2], A. Garcia[2], R. Miller[2], J. Rivera[2], F. Ceballos[2], L. Dartez[2], M. Flores[2], K. Kayal[2], J. Martinez[2], A. Rodriguez-Zermeno[2], A. Miller[2], J. Creighton[3], D. Kaplan[3], J. Clayton[3], C. Biwer[3], D. Day[3], J. Flanigan[3], M. Rohr[3], J. Hinojosa[2], S. Leake[2], A. Mata[2], S. Cohen[2], J. Murray[2], J. Reser[2], P. Rudnick[2], PALFA Consortium, GBNCC Consortium

[1]*University of Texas at Brownsville/University of Texas at San Antonio,* [2]*University of Texas at Brownsville,* [3]*University of Wisconsin-Milwaukee.*

9:00 AM - 6:30 PM

The Arecibo Remote Command Center (ARCC) at the University of Texas at Brownsville is currently engaged in searching for radio pulsars in collaboration various ongoing pulsar surveys. ARCC is an integrated research/education facility that allows students at the high school and undergraduate level to be directly involved with the research at the Arecibo telescope. We discuss the progress of our search effort that current uses PRESTO pulsar search pipelines. Web based tools were developed so that students could rank the pulsar candidates created by the PRESTO analysis. We describe these tools and present our current discoveries.

237.08 – **Resonant Compton Upscattering in High Field Pulsars and Magnetars**

Matthew Eiles[1], Z. Wadiasingh[2], P. L. Gonthier[1], M. G. Baring[2]

[1]*Hope College,* [2]*Rice University.*

9:00 AM - 6:30 PM

The extremely efficient process of resonant Compton upscattering by relativistic electrons in high magnetic fields is believed to be a leading emission mechanism of high field pulsars and magnetars in the production of intense X-ray radiation. New analytic developments for the Compton scattering cross section using Sokolov and Ternov (S&T) states with spin-dependent resonant widths are presented. These new results display significant numerical departures from the traditional cross section using spin-averaged widths as well as from the spin-dependent cross section using the Johnson & Lippmann (J&L) basis states, thereby motivating the astrophysical deployment of this updated resonant Compton formulation with correct S&T states. Useful approximate analytic forms for the cross section near and at the cyclotron resonance are presented for S&T basis states. These physics calculations are applied to an inner magnetospheric model of the hard X-ray spectral tails in magnetars, recently detected by RXTE and INTEGRAL. Relativistic electrons cool rapidly near the stellar surface in the presence of intense baths of thermal X-ray photons. We present accurate resonant Compton cooling rates for electrons, and the resulting photon spectra for magnetic fields above the quantum critical value. These rates and spectra are computed as functions of the magnetospheric colatitude and altitude, demonstrating how this efficient scattering mechanism can produce the characteristically flat spectral tails observed in magnetars.

We are also grateful for the generous support of the National Science Foundation (grants AST- 1009731 and PHY/DMR-1004811), and the NASA Astrophysics Theory Program through grants NNX06AI32G, NNX09AQ71G and NNX10AC59A.

237.09 – **Sifting for Fast Radio Transients in Pulsar Survey Data Using the Spectral Modulation Index**

Laura Spitler[1], J. Cordes[1], S. Chatterjee[1], J. Stone[2]

[1]*Cornell University,* [2]*Barnard College.*

9:00 AM - 6:30 PM

Large-scale surveys for fast radio transients apply single-pulse search algorithms to high time resolution spectral data (i.e. those typical of pulsar surveys). Such surveys are often plagued by radio frequency interference (RFI), which when not properly mitigated, can confuse detection pipelines and lead to a large number of false candidates. We have developed a method to classify a candidate signal based on the modulation of its spectrum using the spectral modulation index. In brief, broadband and narrowband signals have low and high modulation indices respectively, and by choosing a modulation index cutoff, a spectrum can be automatically classified as either broad or narrowband. Our method targets broadband (continuum) transients that have have a non-zero dispersion measure, while RFI is generally broadband at low dispersion measures or narrowband. We show that the spectral modulation index is a powerful tool for identifying RFI and demonstrate the technique with Crab giant pulses and Rotating Radio Transients (RRATs). We also apply it to data taken for the Pulsar ALFA (PALFA) survey being conducted at the Arecibo Observatory and show preliminary results with an emphasis on the data collected with the new Mock spectrometers.

237.10 – **"Faster-than-Light" Pulse Propagation in the Interstellar Medium and Evidence for Birefringence**

Garcia Jr. Alejandro[1], F. A. Jenet[1], P. Demorest[2], I. Stairs[3], K. Stovall[1], A. J. Ford[1], R. B. Miller[1], J. Rivera[1], J. Rivera[1], L. P. Dartez[1], J. G. Martinez[1]

[1]*University of Texas at Brownsville,* [2]*NRAO,* [3]*University of British Columbia, Canada.*

9:00 AM - 6:30 PM

Radiation from radio pulses are known to experience dispersion due to free electrons in the ISM: low frequencies are delayed relative to high frequencies. A very different kind of dispersion is theoretically predicted from the 1420.4 MHz resonance of the ISM's neutral hydrogen. This "anomalous dispersion" makes the group velocity of the pulses larger than the vacuum speed of light. Furthermore, in the presence of a magnetic field this effect will be different for the left and right polarization modes of the pulses. Evidence for superluminal pulses was first found in observations of PSR B1937+21 two years ago. Here, we present followup observations of this pulsar that confirm the detection, show evidence of birefringence, and allow an estimate of the average magnetic field strength.

237.11 – **Two Millisecond Pulsars Discovered by the PALFA Survey and a Shapiro Delay Measurement**

Julia S. Deneva[1], P. Freire[2], PALFA Collaboration

[1]*Arecibo Observatory,* [2]*Max Planck Institute, Germany.*

9:00 AM - 6:30 PM

We present two millisecond pulsars (MSPs) discovered by the PALFA survey, which uses the Arecibo telescope and the seven-beam ALFA receiver to search for pulsars at 1.4 GHz. The PALFA survey is ongoing since 2004 and focuses on low Galactic latitudes ($|b| < 5$deg) in the portions of the Galactic plane visible from Arecibo. One of the two present discoveries, PSR J1955+25, is an isolated MSP with a period of 4.87 ms. The other new pulsar, PSR J1949+31, has a period of 13.14 ms and is in a 1.9-day binary system with a massive companion. The high inclination of the orbital plane of the binary with respect to the plane of the sky has allowed us to measure the Shapiro delay in the system and derive mass estimates for the pulsar and companion based on the delay in pulse arrival times near superior conjunction, when pulses must pass through the companion's gravitational well before reaching Earth. We estimate the pulsar mass to be 1.6(4) $M_\odot$ and the companion mass to be 0.9(1) $M_\odot$. Continued regular timing observations with the Arecibo telescope will refine these estimates over time.

237.12 – **New Discoveries from the PALFA Survey**

Victoria M. Kaspi[1], PALFA Consortium

[1]*McGill Univ., Canada.*

9:00 AM - 6:30 PM

The Pulsar Arecibo L-Band Feed Array (PALFA) survey is a deep 1.4 GHz search for radio pulsars in the Galactic plane. The primary goal of the survey is to find long-period and millisecond pulsars (MSPs) at large distances and high dispersion measures to which previous Arecibo pulsar surveys were not sensitive. One particular science motivation is to find rotationally stable MSPs that can be used in pulsar timing arrays for detecting nanohertz gravitational waves. PALFA has recently made the transition to using the new Mock Spectrometers, which offer a wider bandwidth and better sensitivity than was previously available. To date, PALFA has discovered over 70 new pulsars, including many millisecond pulsars (MSPs). Here, we highlight some of the most recent discoveries, which include some found using the Einstein@Home global volunteer computing system. We also discuss expected future PALFA results.

237.13 – **Continuous Gravitational Wave Searches from Galactic Neutron Stars in the Advanced Detector Era**

Leslie Wade[1], X. Siemens[1], D. Kaplan[1], B. Knispel[2], B. Allen[2]

[1]*UW-Milwaukee,* [2]*AEI: Hannover, Germany.*

9:00 AM - 6:30 PM

We consider a simulated population of galactic neutron stars. The rotational frequency of each neutron star evolves through a combination of electromagnetic and gravitational wave emission. The magnetic field strength determines the dipolar emission, and the ellipticity (a measure of a neutron star's deformation) determines the gravitational wave emission. We find the gravitational wave amplitude emitted by each star in the population and probe the areas of magnetic field strength and ellipticity parameter space

that would result in a detection by Advanced LIGO. We show that in the absence of a detection, for fixed ellipticity, we can set lower bounds on the magnetic fields of young neutron stars.

237.14 – **Chandra Observations of Fermi-LAT and Radio Pulsar Fields**

Michael Thomas Wolff[1], Fermi-LAT Collaboration

[1]*Naval Research Laboratory.*
9:00 AM - 6:30 PM

We continue our campaign of multi-wavelength observations of Fermi-LAT gamma-ray sources utilizing the Chandra ACIS-S instrument. These observations are to search for and determine properties of significant X-ray point sources that might be associated with the recently discovered rotation-powered pulsars J1514-49, J1658-53, J1302-32, J2017+06, and J1103-53. All of these pulsars were originally discovered in radio searches of Fermi-LAT unassociated gamma-ray sources. Chandra can localize X-ray point sources with arc second positional accuracy and characterize their X-ray spectral properties. We report on the X-ray fluxes and spectral properties of the associated X-ray sources found in our observations and compare these properties with those of other rotation-powered X-ray and gamma-ray pulsars. We also discuss other interesting sources uncovered by our observations in the fields of our target pulsars.

This work is supported by Chandra X-ray Observatory Guest Observer Program and the Office of Naval Research.

237.15 – **A Multi-wavelength Campaign to Study Crab Giant Pulses**

Walid A. Majid[1], C. J. Naudet[1], S. T. Lowe[1], T. B. H. Kuiper[1]

[1]*JPL/Caltech.*
9:00 AM - 6:30 PM

We are currently undertaking a monitoring campaign with NASA 70-m antennas to capture a large sample of Crab Giant Pulses (CGP) at multiple radio wavelengths. The goal of this campaign is to carry out a correlation study of CGPs at radio frequencies with pulsed emission from the Crab pulsar with Fermi photons at X-ray. After a year of this study, we expect around 200 Fermi photons to coincide with a CGP radio-frequency detection, allowing us to either confirm a predicted correlation in average gamma-ray pulsed flux increase with GP emission, or place a tight upper limit, at least a factor of 10 more constraining than previous work. We will report on the status of this campaign over the next year. We will also provide a brief summary of available receivers and spectrometer back-ends and will discuss our upgrade plans for the L-band system to cover the 1400-1900 MHz band in two polarizations in order to increase our sensitivity to a fainter population of CGPs.

237.16 – **A New Search of Unidentified Radio Point Sources for Fast Pulses and Bursts**

Deborah Schmidt[1], F. Crawford[1], G. Langston[2], C. Gilpin[1]

[1]*Franklin & Marshall College,* [2]*National Radio Astronomy Observatory.*
9:00 AM - 6:30 PM

We are searching 92 unidentified sources from the Faint Images of the Radio Sky at Twenty Centimeters (FIRST) and NRAO VLA Sky Survey (NVSS) 1400 MHz radio survey catalogs in an attempt to detect fast millisecond (or possibly submillisecond) pulsars and short radio bursts that might have been missed by previous surveys. The selected sources are bright, pointlike, and more than 5% linearly polarized, and have no identification with extragalactic objects. These sources were previously observed with the Jodrell Bank Telescope and searched for radio pulsations by Crawford, Kaspi, & Bell (2000). We have observed these sources again using the 43-m Telescope at NRAO in Green Bank. We employed the West Virginia Ultimate Pulsar Processor Instrument (WUPPI), which is capable of recording spectral samples every 0.00006144 seconds. WUPPI was configured for 800 MHz bandwidth, with 4096 channels, centered on 1200 MHz sky frequency. The much wider bandwidth used in this search allows a better discrimination between interference and dispersed radio signals and reduces the likelihood of missing pulsars due to scintillation. The repetition of this search at a different observing epoch is warranted, since emission from compact objects has been observed to be highly time variable in some cases. We report on the progress of this survey.

237.17 – **A Large-Bandwidth High Frequency Survey for Radio Pulsars in the Galactic Center**

Robert Wharton[1], W. Majid[2], J. Deneva[3]

[1]*Cornell University,* [2]*Jet Propulsion Laboratory,* [3]*Arecibo Observatory.*
9:00 AM - 6:30 PM

We are currently undertaking a deep survey for radio pulsars in the Galactic Center (GC) using the DSS28 telescope at the Goldstone Deep Space Communications Complex. The detection of a pulsar in the inner parsecs of the GC would provide an excellent probe of the GC environment and the central supermassive black hole. Despite the detection of over 1800 pulsars in the Galaxy so far, none have been found within 10' of the GC. This is mainly due to the large pulse broadening times (~$2000\nu^{-4}$ seconds for a pulsar in the GC) caused by the scattering of radio waves. The 34 meter DSS28 dish has been outfitted with a wide bandwidth receiver capable of providing 8 GHz of instantaneous bandwidth distributed within a frequency range of 2-14 GHz. The high observing frequencies will help mitigate the pulse broadening due to scattering and the high bandwidth will prove useful in both periodicity and single pulse searches. Overall, the DSS28 telescope provides a unique opportunity for a multi-month directed search for radio pulsars in the GC at high frequencies.

237.18 – **Feasibility Study: Lofar Meridian All-sky Survey (LoMASS)**

Claire Gilpin[1], J. Hessels[2], J. van Leeuwen[2], B. Stappers[3], V. Kondratiev[2], A. Alexov[4], LOFAR Pulsar Working Group and Transients Key Science Project

[1]*Franklin and Marshall College,* [2]*ASTRON, Netherlands,* [3]*University of Manchester, United Kingdom,* [4]*Universiteit van Amsterdam, Netherlands.*
9:00 AM - 6:30 PM

LOFAR provides many opportunities to do efficient and sensitive all-sky surveys for pulsars and other steep spectrum fast transients. LOFAR observations of known pulsars reveal a number of sources that show sporadic but bright individual pulses in the 15-80MHz range. Blind searches for new objects exhibiting these properties would probe the sky in a new way and could be very scientifically rewarding. There is also the possibility of finding pulsars that are only visible at very low radio frequency because the emission beam is wider. The feasibility of doing a very low-frequency (~30MHz) all-sky survey with high time resolution was studied for a pilot project called LoMASS, the LOFAR Meridian All-Sky Survey. An observing configuration comprised of an arc of low-band-antenna station beams aligned along the meridian will be used in order to complete all-sky coverage within 24 hours of observing. Observations of PSR B0809+74 were taken using 1, 8, and 15 station beam configurations. Both 20 minute and 1 hour integration times were tested and the data from the station beams were summed both incoherently and coherently. We report on the results of these initial observations and on our future plans for the survey.

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238 – Laboratory Astrophysics

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

238.01 – **Laboratory Studies of Solid Carbon Dioxide in Planetary and Interstellar Ices**

Douglas White[1], R. M. Mastrapa[2], S. A. Sandford[1]

[1]*NASA Ames Research Center,* [2]*SETI Institute.*
9:00 AM - 6:30 PM

Laboratory spectra have shown that CO_2 is a powerful diagnostic tool for analyzing infrared data from remote observations, as it has been detected on icy moons in the outer solar system as well as dust grain surfaces in the interstellar medium. IR absorption profiles of CO_2 within ice mixtures containing H_2O and CH_3OH change with respect to temperature and mixture ratios. In this particular study, the CO_2 stretch mode around 2350cm^{-1} (4.3 microns) is systematically observed in different mixtures with H_2O and CH_3OH in temperature ranges from 15 K to 150 K, as well as vibrational modes in the near-IR such as the combination bands near 3700 cm^{-1} (2.7 microns) and 5080 cm^{-1} (2.0 microns). Additionally, some high-temperature deposits (T > 50 K) of H_2O, CH_3OH, and CO_2 ice mixtures were performed to determine the maximum temperatures at which CO_2 will deposit on the sample window. These data may then be used to interpret spectra obtained from remote IR observations. This research was sponsored by Oak Ridge Associated Universities (ORAU) through the NASA Postdoctoral Program (NPP) as well as Ames Research Center and the SETI institute who provided facilities and equipment.

238.03 – **Far-Infrared Optical Properties of Iron-Silicate Dust Analogues**

Raymond Kinzer[1], S. Rinehart[1], D. Benford[1], G. Cataldo[1], E. Dwek[1], R. Henry[1], J. Nuth[1], C. Richey[1], R. Silverberg[1], E. Wollack[1]

[1]*Goddard Space Flight Center.*
9:00 AM - 6:30 PM

Astronomical dust is observed in a variety of astrophysical environments and plays an important role in radiative processes and chemical evolution in the galaxy. Depending upon the environment, dust can be either carbon-rich or oxygen-rich (silicate grains). Astronomical observations and ground-based data show that the optical properties of silicates can change dramatically with the crystallinity of the material, and recent laboratory research provides evidence that the optical properties of silicate dust vary as a function of temperature as well. Therefore, correct interpretation of a vast array of astronomical data relies on the understanding of the properties of silicate dust as functions of wavelength, temperature, and crystallinity. The OPASI-T (Optical

Properties of Astronomical Silicates with Infrared Techniques) project addresses the need for high quality optical characterization of metal-enriched silicate condensates using a variety of techniques. A combination of both new and established experiments are used to measure the extinction, reflection, and emission properties of amorphous silicates across the infrared, thus providing a comprehensive data set characterizing the optical parameters of dust samples. We present room temperature and cryogenic spectroscopic data, the various experimental apparatus and measurement techniques, and the computed optical constants for a sample of iron-silicate dust analogues.

238.04 – **A New Large Echelle Spectrometer for Measuring Atomic Transition Probabilities of Fe-group Ions**

Michael Wood[1], J. E. Lawler[1]

[1]*University of Wisconsin-Madison.*

9:00 AM - 6:30 PM

Accurate atomic transition probabilities for weak lines connected to the ground and low metastable levels of Fe-group ions are needed for elemental abundance studies on metal-poor stars. Metal-poor stars represent the oldest observable stellar generation and offer a direct probe into the early history of nucleosynthesis and the chemical evolution of the Galaxy. Unexplained trends in relative Fe-group abundances, such as [Co/Cr], as a function of metallicity, or [Fe/H], have been observed. These trends may result from a breakdown in the local thermodynamic equilibrium (LTE) approximation used in traditional photosphere models underlying elemental abundance determinations. The ground and low metastable levels of Fe-group ions contain most of the Fe-group material in a stellar photosphere, and thus second spectra lines with low E.P.s are essentially immune to non-LTE effects. To improve lab data on important Fe-group lines we have developed a novel instrument based on a 3 meter focal length vacuum echelle spectrograph combined with an aberration corrected cross dispersion system and a UV sensitive CCD array. This spectrometer is capable of recording both emission and absorption spectra with high resolving power, very broad wavelength coverage, and high signal-to-noise. It is also free from the multiplex noise of a FTS, making it ideally suited for measuring branching fractions of very weak lines. The combination of very accurate branching fractions with radiative lifetimes from time-resolved laser-induced fluorescence will yield accurate absolute transition probabilities of weak second spectra lines with low E.P.s for the Fe-group elements. Instrument design and preliminary results will be presented.

Supported by NASA Grant NNX09AL13G.

238.05 – **Laboratory Far-infrared Spectroscopy Of Terrestrial Phyllosilicates To Support Analysis Of Cosmic Dust Spectra.**

Mehmet Yesiltas[1], T. Brusentsova[1], R. Peale[1], D. Maukonen[1], P. Figueiredo[1], G. H. Harlow[2], D. S. Ebel[2], A. Nissinboim[2], K. Sherman[2], C. M. Lisse[3]

[1]*University of Central Florida,* [2]*American Museum of Natural History,* [3]*Johns Hopkins University.*

9:00 AM - 6:30 PM

Poster Abstract: 219th AAS Meeting

M. Yesiltas[1], T. Brusentsova[1], R. E. Peale[1], D. Maukonen[1], P. Figueiredo[1], G. E. Harlow[2], D. S. Ebel[2], A. Nissinboim[2], K. Sherman[2], and C. M. Lisse[3]

Remote spectral detection of hydrated minerals is of general interest in the solar system and dusty circumstellar disks. This paper presents spectroscopy of terrestrial phyllosilicate minerals in the wavelength range 15 - 250 μm to support interpretation of returned data from far-IR space-missions such as the Herschel Space Observatory. The far-IR spectral region beyond 15 micron wavelength is especially diagnostic of mineral composition and crystal structure. Relatively little far-IR spectral data exists in the literature on suitably-characterized naturally-occurring phyllosilicate minerals in the wavelength range 60-210 microns corresponding to the PACS instrument of Herschel Space Observatory. Extending the database of laboratory far-IR spectra of terrestrial mineral analogs is therefore desirable and timely. Seventeen phyllosilicate minerals expected in various astronomical environments were sampled from the American Museum of Natural History for diversity and astrophysical relevancy, based on their identification in Stardust, in stratospheric IDP samples, or in meteorites. These include serpentines (Antigorite and Chrysotile), smectites (Talc, Pyrophyllite, Vermiculite, Montmorillonite, Beidellite, Saponite, Nontronite and Hectorite), chlorites (Clinochlore), micas (Muscovite, Paragonite, Margarite, Clintonite, Biotite and Illite), and kaolinites (Dickite, Nacrite, Kaolinite, Halloysite, Attapulgite and Sepiolite). Spectra of ~micron-sized powder suspensions in polyethelyne pellets reveal prominent and characteristic far-IR features, which differ significantly in some cases from already published spectra, where available.

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238.06 – **The Z Astrophysical Plasma Properties (ZAPP) Collaboration**

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9:00 AM - 6:30 PM

Astrophysically-relevant laboratory plasmas with energy densities, volumes, and durations far beyond what was previously possible are being investigated using ***Z***, a z-pinch facility at Sandia National Laboratories that generates electrical power bursts that exceed the entire world's generating capacity. The Z Astrophysical Plasma Properties (ZAPP) collaboration unites a number of universities and national labs, making use of the unique x-ray source capabilities at the ***Z*** facility to simultaneously drive four independent experiments. These experiments create plasmas with a range of conditions (T_e=10^4 - 10^6 K, n_e=10^{16} - 10^{23} cm^{-3}) and are targeted at advancing the knowledge of (1) solar/stellar interior opacities, (2) active galactic nuclei warm-absorber photo-ionized plasmas, (3) the role of resonant Auger destruction in spectral line emission from accretion powered objects, and (4) spectral line profiles in white dwarf photospheres. These topics are diverse, but they are all heavily influenced by fundamental properties of atoms in plasmas. Our strategy is to reproduce the characteristics of astrophysical conditions as closely as possible in the laboratory and use the measurements to strengthen models for atoms in plasmas. These refined models can then be used more reliably and with greater accuracy in the astrophysics community.

238.07 – **Developing an Experimental Platform to Create White Dwarf Photospheres in the Laboratory**

Ross Falcon[1], G. A. Rochau[2], J. E. Bailey[2], J. L. Ellis[1], A. L. Carlson[2], T. Gomez[1], M. H. Montgomery[1], D. E. Winget[1], M. R. Gomez[2]

[1]*University of Texas at Austin,* [2]*Sandia National Laboratories, NM.*

9:00 AM - 6:30 PM

We continue to improve upon the laboratory astrophysics experiments to create macroscopic (~9-38 cm^3) hydrogen plasmas with white dwarf (WD) photospheric conditions (electron temperature and density). Falcon et al. (2010) demonstrate the ability to create the plasma and to observe time-resolved spectra throughout its ~400 ns lifetime. We extend the observations from emission to absorption spectra, improve the design of the experimental platform, and discuss the astrophysical motivations, spearheaded by recent work in WD spectroscopy and atmosphere modeling.

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239 – Planetary Nebulae, Supernova Remnants

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

239.01 – **The Energetics of Jets in Proto-Planetary Nebulae**

Patrick J. Huggins[1]

[1]*New York University.*

9:00 AM - 6:30 PM

The rapid evolution of stars from the Asymptotic Giant Branch to the planetary nebula phase is often accompanied by powerful, high velocity jets whose origins are not well understood. We compare current theoretical ideas for the production of jets with observations, using a sample of proto-planetary nebulae whose dynamical properties are well-studied in the millimeter lines of CO. In addition to the jets, we find that the mass and energetics of the equatorial mass-loss that typically accompanies the jets are important diagnostics. Our integrated approach provides estimates for some key physical quantities, such as the binding energy of the envelope when the jets are launched, and allows us to investigate model features using correlations between parameters. Even with a relatively small sample, we find that some specific scenarios for powering jets can be ruled out or rendered implausible, and others are promising at a quantitative level.

239.02 – **The Herschel Planetary Nebula Survey (HerPlaNS)**

Djazia Ladjal[1], HerPlaNS consortium

[1]*University of Denver.*
9:00 AM - 6:30 PM

HerPlaNS is a Herschel Open Time program that exploits the unprecedented spatial resolving power in the far infrared of the Herschel Space Observatory to investigate a sample of 11 planetary nebulae (PNe). The aim of the program is to study the distribution of cold dust in the nebulae, using the PACS and SPIRE imaging modes, and to diagnose the physical conditions of the gas component in the nebulae using the PACS and SPIRE spectroscopy modes. In addition to investigating a completely new wavelength range (60--670um), combining the imaging and spectroscopy will allow us to build a more complete picture of the interplay between the dust and gas as a function of location in the nebulae. In this poster we will present the HerPlaNS program, its aim, the adopted observing technics and a glimpse of our preliminary results.

239.03 – **Searching for Planetary Nebulae in Open Star Clusters**

Julie H. Lutz[1], K. Braxton[1], J. McKeever[2], T. Gomez[3], B. Balick[1], H. Gunning[1], M. Spencer[1], A. Tran[1]

[1]*Univ. of Washington,* [2]*Univ. of New Mexico,* [3]*Univ. of Texas.*
9:00 AM - 6:30 PM

Determining distances to planetary nebulae (PNe) has been a major challenge in understanding the roles played by these objects in stellar evolution. Several PNe have been found in globular clusters, but a large systematic search for PNe in open star clusters has yet to be performed. Recently, a couple of probable associations between PNe and open clusters have been presented, those results lead us to begin a search for additional possibilities. H-alpha and Sloan r' images of 70 open clusters were obtained during summer 2010 with the 0.75-m telescope at the University of Washington's Manastash Ridge Observatory (MRO). The selection criteria for clusters included: availability during the summer months and size constraints due to the telescope's field of view. We also chose clusters of intermediate ages. These clusters were examined for objects that stood out in the H-alpha filter. Follow-up observations were conducted during the summer of 2011 with [O III] and Sloan g' and i' filters on a subset of clusters that appeared to have objects of interest. We present the results of our open cluster survey

239.04 – **Comparative Study Of Outer Halos Of Planetary Nebula NGC 246, NGC 1501, And NGC 2022**

Douglas N. Arion[1], S. Finnvik[1], Z. Troyer[1]

[1]*Carthage College.*
9:00 AM - 6:30 PM

A number of planetary nebulae exhibit multiple shell structures, including concentric outer halos. Three such nebulae have been studied by obtaining deep images in [O III] to identify linkages between structures observed in the inner nebula and structures found in the outer halos. Three different planetaries were studied - NGC 246, 1501, and 2022, and all exhibit similar morphologies, suggesting similar evolutionary pathways. Of note are jet structures that appear to extend through all of the shell/halo layers, implying that the layers were ejected before the jets. Data were obtained on the 0.9m WIYN telescope at Kitt Peak National Observatory and the 1.52m Kuiper Telescope of the University of Arizona Steward Observatory. This work was supported in part by the Wisconsin Space Grant Consortium and a private bequest from Ms. Linda Staubitz.

239.05 – **Luminosity And Abundance Correlations In A Carefully-studied Sample Of PNe**

Bruce Balick[1], J. McKeever[2], J. Lutz[1], K. Braxton[1], T. Gomez[3]

[1]*Univ. of Washington,* [2]*New Mexico State Univ,* [3]*Univ. of Texas at Austin.*
9:00 AM - 6:30 PM

We have searched for correlated trends in He/H, N/H, O/H, Ne/H, Ar/H, Cl/H, and S/H abundances with their luminosities, Peimbert types, galactocentric radius, emission-line luminosities, diameters, morphologies, surface brightnesses among Galactic planetary nebulae (PNe) using a database of 119 PNe with well measured properties. The various major new results are presented.

239.06 – **Ionization Corrections for Deriving Se and Kr Abundances in Ionized Nebulae**

Nicholas C. Sterling[1], R. L. Porter[2]

[1]*Michigan State University,* [2]*University of Georgia.*
9:00 AM - 6:30 PM

We present new analytical ionization correction factors (ICFs) for deriving Se and Kr abundances in photoionized nebulae. Recent observations have revealed emission lines of neutron(n)-capture elements (atomic number Z>30) in planetary nebulae (PNe), H II regions, and starburst galaxies. These detections demonstrate the potential of nebular spectroscopy for investigations of n-capture nucleosynthesis and the chemical evolution of trans-iron elements. However, the lack of atomic data needed to produce robust ionization balance solutions for n-capture elements has prevented the determination of accurate abundances for these elements.

We expanded the atomic database of the Cloudy photoionization code (Ferland et al. 1998, PASP, 110, 761) to include elements up to Kr, incorporating newly-computed photoionization cross sections and rate coefficients for radiative recombination, dielectronic recombination, and charge transfer for low-charge ions of Se and Kr (Sterling & Witthoeft 2011, A&A, 529, A147; Sterling 2011, A&A, 533, A62; Sterling & Stancil 2011, A&A, in press (arxiv:1108.3838)). We have computed a grid of models over a large range of stellar temperatures, luminosities, and nebular densities for PNe and H II regions. By comparing the fractional abundances of observed Se and Kr ions to those of commonly detected ions, we derived new analytical ICFs for unobserved Se and Kr ions. We also present preliminary results of the sensitivity of abundance determinations to atomic data uncertainties. These results enable accurate n-capture element abundances to be derived from nebular spectra for the first time, and will be applied to Se and Kr detections in PN spectra. N. C. Sterling gratefully acknowledges support from an NSF Astronomy and Astrophysics Postdoctoral Fellowship under award AST-901432.

239.07 – **Kinematical Structure of the Planetary Nebula NGC 7009**

Seong-Jae Lee[1], S. Hyung[1]

[1]*Chungbuk National University, Korea, Republic of.*
9:00 AM - 6:30 PM

We investigated the line profiles of the planetary nebula NGC 7009 using the (10-m) Keck HIRES and (1.8-m) BOES spectral data, obtained in 1998, August 14-16 and 2009, October 2. The HIRES long-slit data were secured along the major and minor axes, while the BOES fiber data were obtained from the central region of the nebula. The Keck 2D kinematical data, i.e., sky-field vs. velocity frame, suggest some interesting features. We confirmed the high density inner boundary of the main shell consisting of numerous high density structures, a receding hot-bubble like structure & approaching 2-3" high density blobs in W-SW cap region; and sub-arc second scale blobs in the hollow zone along the major axis. We also identified the density range of the main & outer shells near S-SE bright rim and 2" diameter hot bubble-like structure near the N-NW bright rim along the minor axis. For the 5 strategically important positions, E-NE & W-SW caps; S-SE & N-NW rims; and CSPN, we decomposed the one-dimensional spectral line profiles of the important lines in the wavelength range of 3250-8725A. The analyzed lines are HeI5875, 6678, 7065; HeII7592, 4686; [OII]7319; [OIII]4363, 4959, 5007; [NII]6548, 6583; NIII4097; [SII]6716, 6730; [SIII]6312, 9068; [ArIII]7136, 7751; [ArIV]4711, 4740; and [ClIV]7529, 8045. Most of the low-to-medium excitation lines and some of high excitation lines showed double + 3rd wing components. The 3rd wing component in the low-to-medium excitation lines are due to the outer ring or high density blobs, but in some cases, the fast blue or red wing component found in the low-to-medium lines profile is likely to be an independent geometrical feature, similar to the jet-like outflows. Inside the main shell, there appears to be an inner zone that is responsible for some unusual feature in the high excitation HeI and HeII line profiles.

239.08 – **Carbon and Silicate Dust Condensation in Type II Supernovae**

Ethan A.N Deneault[1], B. Morales[1]

[1]*Univ. Of Tampa.*
9:00 AM - 6:30 PM

We investigate the chemistry of formation and destruction processes of molecules in the expanding and cooling ejecta of Type II Supernovae. In this work, we use a kinetic chemistry network to explore the parameters and conditions of the ejecta which are required for the condensation of graphite and silicon carbide grains.

239.09 – **Measurement of Flux Density of Cas A at Low Frequencies**

Ajinkya Patil[1], R. Fisher[2]

[1]*Indian Institute of Technology Kharagpur, India,* [2]*NRAO.*
9:00 AM - 6:30 PM

Cas A is used as a flux calibrator throughout the radio spectrum. Therefore it is important to know the spectral and secular variations in its flux density. Earlier observations by Scott et. al. (1969) and Baars et. al. (1972) suggested a secular decrease in flux density of Cas A at a rate of about 1% per year at all frequencies. However later observations by Erickson & Perley (1975) and Read (1977) indicated anomalously high flux from Cas A at 38 MHz. Also, these observations suggested that the original idea of faster decay of the flux density rate at low frequencies may be in error or that something more complex than simple decay is affecting the flux density at low frequencies. The source changes at 38 MHz still remains a mystery. We intend to present the results of follow up observations made from 1995 to 1998 with a three element interferometer in Green Bank operating in frequency range 30 to 120 MHz. We will discuss the problems at such low frequencies due to large beamwidth and unstable ionosphere. We will also discuss the strategies we have used so far to to find the flux density of Cas A by calculating the ratio of flux density of Cas A to that of Cyg A, assuming flux density of Cyg A to be constant.

Above mentioned work was performed in summer student program sponsored by

National Radio Astronomy Observatory.

239.10 – **The Progenitor of Type Ia SNR 0519-69.0 Was Either a Persistent Supersoft X-ray Source or Double-Degenerate System**

Zachary Edwards[1], A. Pagnotta[2], B. E. Schaefer[2]

[1]*Columbus State University,* [2]*Louisiana State University.*
9:00 AM - 6:30 PM

One of the main problems in astrophysics is the unknown nature of the Type Ia Supernova (SN Ia) progenitor system. Current models of SNe Ia involve the detonation of a Carbon-Oxygen (CO) white dwarf (WD) that has reached the Chandrasekhar Limit (1.4 Msun) via mass transfer from a companion star. Many different types of progenitor systems have been proposed that involve various possible companion stars. These can be divided into the double-degenerate (DD) model, which contains two WDs, and the single-degenerate (SD) model, which contains one CO WD and a main-sequence, sub-giant, or giant companion star. By examining remnants of known SNe Ia, we can search for any ex-companion star and thereby infer the progenitor system for a given SN Ia. It was inferred by Schaefer & Pagnotta (2011) that the progenitor of SNR 0509-67.5 was a DD system since the central region was devoid of any stars to deep limits. Using archival Hubble Space Telescope images we eliminated all but two of the various proposed models for SNR 0519-69.0, which is known to be a SN Ia based on its light-echoes (Rest et al. 2005, Hughes et al. 1995). The geometric central region was determined using both the Hα and the X-ray shell to be RA= 05:19:34.84, DEC= -69.02.06.92 (J2000). We report the stars in the geometric central region to a limiting V magnitude of 26.1. Photometric analysis of these central stars shows that none of them are red giants or subgiants. We know of only two models that are consistent with our observational limits: persistent supersoft X-ray sources and DDs. We will soon use Gemini to obtain spectra of stars in the central region of SNR 0519-69.0, and may be able to report on this at the meeting.

239.11 – **Improved Ionization Correction Factors for Planetary Nebula Abundance Determinations**

Timothy R. Miller[1], R. B. C. Henry[1], G. J. Ferland[2]

[1]*University of Oklahoma-Norman,* [2]*University of Kentucky.*
9:00 AM - 6:30 PM

An ionization correction factor (ICF) is a quantity which accounts for the contribution of unobserved ions when determining an element's total abundance. We present improved methods for calculating ICFs for many metals including oxygen, carbon, and neon. We use a grid of over 500 planetary nebula models generated by the program Cloudy, covering ranges in Teff, gas density, and metallicity of 30,000K to 500,000K, 100 to 30,000 cm^{-2}, and $10^{-0.6}$ to $10^{0.4}$ times solar, respectively. In the important case of oxygen, we find that a constant ICF of 1.076 for models with 30,000K ≤ Teff ≤ 100,000K generates a relative percent error no larger than 6.07%.

239.12 – **X-ray, Optical and Radio Observations of the Extragalactic Superbubble N7793-S26**

Thomas Pannuti[1], E. M. Schlegel[2], M. D. Filipovic[3], E. Crawford[3], J. Payne[3], C. K. Grimes[1]

[1]*Morehead State University,* [2]*University of Texas-San Antonio,* [3]*University of Western Sydney, Australia.*
9:00 AM - 6:30 PM

We present a multi-wavelength (X-ray, optical and radio) spatial and spectral analysis of the extragalactic superbubble N7793-S26. Prior observations and analysis of this source had revealed extended emission spanning nearly 400 parsecs at all three wavelength domains: the extended morphology of this object suggests a superbubble classification, prompting the argument that N7793-S26 is actually a microquasar. We investigate the microquasar interpretation of this source based on analysis of its spatial and spectral properties and compare N7793-S26 to another known extragalactic superbubble located in the Local Group Galaxy IC 10. We investigate the scenario that the soft X-ray sources seen at the northern and southern edges of N7793-S26 are actually supernova remnants and that the central hard X-ray source is an X-ray binary serendipitously located to give the appearance of a central engine with two jets. This scenario will be presented and discussed.

239.13 – **Limits On The Brightness Of A Compact Object In The Remnant Of SN 1987a**

Dominic Pesce[1]

[1]*Harvard College.*
9:00 AM - 6:30 PM

I have been doing work on Supernova 1987A (SN 1987A) in an attempt to set a limit on the presence of a stellar remnant - specifically, a neutron star - amidst the supernova debris. The observations used were taken by the SAINTS group in 2009 and 2011 with the Wide Field Camera 3 (WFC3) on the Hubble Space Telescope (HST), and they span several wavebands from the ultraviolet to the infrared. To begin establishing the limit, we posed the following question: what is the maximum brightness that an object in the supernova remnant could have while still remaining hidden by the debris?

The first step was to remove as much excess light from the image as possible. This light came primarily from diffraction from the "hotspots" on the circumstellar ring and the nearby stars. By modeling the ring as a series of point spread functions (PSFs), we were able to subtract out much of the pollutant light from the image. The diffraction from the surrounding stars was also removed via PSF subtraction.

The next step was to determine the value of the limit. This was done using a piece of code that inserted a PSF with unknown position and brightness into an image of the remnant. This was done repeatedly for each filter, and for each new image the code recorded whether the user had detected the PSF within the image. After many iterations of this code, a "gray area" was established for each filter, where an inserted PSF of a given brightness was sometimes detected and sometimes not. This gray area was averaged over, and we called this our limit.

The upper limit on the optical luminosity of a compact object within the remnant of SN 1987A came out to be $L_{opt} \leq 1.6 \times 10^{33}$ erg/s (0.42 L_{Sun}).

239.14 – **X-Ray Imaging of Galactic Supernova Remnant G299.2-2.9**

Seth Post[1], C. Badenes[2], D. N. Burrows[3], J. P. Hughes[4], J. Lee[5], K. Mori[6], S. Park[1], P. Slane[7]

[1]*The University of Texas at Arlington,* [2]*University of Pittsburgh,* [3]*Penn State,* [4]*Rutgers,* [5]*Korea Astronomy and Space Science Institute, Korea, Republic of,* [6]*University of Miyazaki, Japan,* [7]*Smithsonian Astrophysical Observatory.*
9:00 AM - 6:30 PM

We present images of Galactic supernova remnant (SNR) G299.2-2.9 obtained from data collected from a 640 ks exposure with the ACIS-I array on board the Chandra X-Ray Observatory. For the first time, we resolve the entire SNR, including the complete faint central nebula region which is composed of metal-rich ejecta, using Chandra high-resolution imaging spectroscopy. Two previously unobserved, very faint shell-like structures are detected along the northern and southern ends of the SNR, each extending past the diffuse emission that surrounds the bright shell. We present hardness ratio maps and equivalent width images from emission lines of several elements to identify spatial variations in the electron temperature and line strengths throughout the SNR. We discuss some preliminary results from our spectral analysis of several sub-regions of metal-rich ejecta and shocked ambient material.

239.15 – **The Molecular Content of the Crab Nebula**

Charles A. Kuehn[1], E. D. Loh[1], J. A. Baldwin[1], G. J. Ferland[2], A. C. Fabian[3], C. T. Richardson[1], P. Salome[4], C. R. O'Dell[5]

[1]*Michigan State University,* [2]*University of Kentucky,* [3]*University of Cambridge, United Kingdom,* [4]*Observatoire de Paris, France,* [5]*Vanderbilt University.*
9:00 AM - 6:30 PM

We are using a combination of archival NASA ADAP data and new ground-based observations to study molecular cores in the Crab Nebula's filaments. This component of the Crab has largely been ignored since the pioneering discovery, by Graham, Wright & Longmore (1990), of H2 emission at two locations. Many of the absorbing dust blobs long known to exist in the Crab also are likely to be associated with these molecular cores. Some important open questions are: How much mass is in the molecular component? What excites the H2 emission? How were the molecules formed? What is the nature of the dust? Where/when/how was the dust formed? Are these structures similar to cool-core cluster filaments, which also emit strongly in H2?

Our new ground-based NIR images and spectra show many additional H2 knots scattered along the Crab's filaments. We are currently analyzing the large grid of Spitzer GTO long-slit and high-resolution IRS spectra of the Crab, which include many of the molecular cores. We have supplemented them with a grid of long-slit optical spectra at the exact same positions, giving spectral coverage over a wide range of emission lines from ionized, neutral and atomic gas. We are adding CO observations at selected points, to further constrain the properties of the molecular cores. HST [O III] and [S II] images show the structure of individual molecular knots at 10^{17} cm resolution. We also are carrying out a new survey of dust features using archival HST continuum images, to better determine how dust fits into the picture. Spitzer and Herschel images provide a lower-resolution look covering the dust thermal emission peak. Our aim is to assemble the necessary pan-chromatic data set and then construct accurate plasma simulation models that will allow us to answer the questions posed above.

239.16 – **An Archival XMM-Newton Study of the Large Magellanic Cloud Supernova Remnant N132D**

Paul P. Plucinsky[1], A. R. Foster[1], T. J. Gaetz[1], D. Jerius[1], D. J. Patnaude[1], R. J. Edgar[1], R. K. Smith[1], W. P. Blair[2]

[1]*Harvard-Smithsonian, CfA,* [2]*Johns Hopkins University.*
9:00 AM - 6:30 PM

We present the results of an analysis of the archival XMM-Newton EPIC data (totaling

more than 500ks) of the brightest X-ray supernova remnant (SNR) in the Large Magellanic Cloud (LMC) N132D. N132D has been routinely observed by XMM-Newton over its 11 year mission as a calibration target. We have combined the data from all calibration observations suitable for scientific analysis to create the deepest X-ray images of N132D. N132D has been classified as an ``Oxygen-rich'' remnant based on the UV and optical spectra which show emission from

C, O, Ne, Mg, and Si. These spectra of the bright optical knots do not show any emission from elements with higher Z than Si, yet the nucleosynthesis models predict significant quantities of these higher Z elements. Our preliminary analysis of the deep XMM data clearly shows emission lines from S, Ar, Ca, and Fe, with indications of other possible lines between Ca and Fe. We compare the estimated amount of these high Z elements to various nucleosynthesis models to constrain the possible progenitor.

This research was supported by the NASA Astrophysics Data Analysis Program (ADAP) through grant number NNX11AD17G.

239.17 – **The X-ray Structure Of The Supernova Remnant And Pulsar-wind Nebula in DEM L 241**

Rosa Nina Murphy Williams[1], F. Seward[2], J. Dickel[3], Z. Edwards[1], B. Furnish[1], M. Perry[1], T. Williams[1]

[1]Columbus State University, [2]Harvard-Smithsonian Center for Astrophysics, [3]University of New Mexico.
9:00 AM - 6:30 PM

High energy astrophysics offers us the ability to further understand pulsars (PSR), pulsar wind nebulae (PWN), and their interaction with the host supernova remnant (SNR). SNR DEM L241, located in the Large Magellanic Cloud, allows us to study a complex SNR in close proximity and low absorption. DEM L241 is also ideal for this study due to the separation of the internal PSR and PWN. Using data provided by the Chandra Space Telescope we were able to analyze spatially resolved spectra and calculate physical properties for various regions of the remnant in order to better understand the evolution of the SNR and PWN, and their interactions with each other and the interstellar medium.

The authors thank NASA's Chandra grant G01-12094C and LTSA grant NNX08AM54G for support of this project.

239.18 – **Modeling the Binary Central Stars of the Planetary Nebulae Sp 1 and NGC 6337**

Todd C. Hillwig[1], S. Margheim[2], O. De Marco[3]

[1]Valparaiso University, [2]Gemini Observatory, [3]Macquarie University, Australia.
9:00 AM - 6:30 PM

Current estimates of the impact of close binary stars on the shaping and ejection of common envelopes and planetary nebulae include a number of systems for which little published data and/or no binary parameters exist in the literature. Only six of the approximately 45 currently catalogued binary systems have been well studied. With the current emphasis in planetary nebula research on determining the role of binarity in the planetary nebula process, and the importance of post common envelope systems in our understanding of many important astrophysical systems it is imperative that we understand as well as possible the small number of detected binary systems. We present light curves, spectra, and radial velocity curves for the close binary central stars of the planetary nebulae Sp 1 and NGC 6337. Both systems are low inclination irradiated binaries with a cool main sequence companion to the hot central star. We have used the Wilson-Devinney code to place strong constraints on the physical parameters of each system. We relate our results to larger issues such as the ejection and formation of planetary nebulae, close binary evolution, and common envelope evolution.

239.19 – **Circumstellar Dust in the Remnant of Kepler's Type Ia Supernova**

Brian J. Williams[1], W. P. Blair[2], K. J. Borkowski[1], P. Ghavamian[3], K. S. Long[4], S. P. Reynolds[1], R. Sankrit[5]

[1]North Carolina State University, [2]Johns Hopkins University, [3]Towson University, [4]Space Telescope Science Institute, [5]SOFIA/USRA.
9:00 AM - 6:30 PM

Kepler's Supernova Remnant, the remains of the supernova of 1604, is widely believed to be the result of a Type Ia supernova, and shows IR, optical, and X-ray evidence for an interaction of the blast wave with a dense circumstellar medium (CSM). We present low-resolution 7.5-38 μm IR spectra of selected regions within the remnant, obtained with the *Spitzer Space Telescope*. Spectra of those regions where the blast wave is encountering circumstellar material show strong features at 10 and 18 μm. These spectral features are most consistent with various silicate particles, likely formed in the stellar outflow from the progenitor system during the AGB stage of evolution. While it is possible that some features may arise from

freshly formed ejecta dust, morphological evidence suggests that it is more likely that they originate from dust in the CSM. We isolate the dust grain absorption efficiencies for several regions in Kepler and compare them to laboratory data for dust particles of various compositions. The hottest dust in the remnant originates in the regions of dense, radiatively shocked clumps of gas, identified in optical images. Models of collisionally heated dust show that such shocks are capable of heating grains to temperatures of > 150 K. We confirm the finding that Kepler's SNR is still interacting with CSM in

at least part of the remnant after 400 years. The significant quantities of silicate dust are consistent with a relatively massive progenitor.

239.20 – **Shock Acceleration Efficiency in Kepler's Supernova Remnant**

Stephen P. Reynolds[1], B. Williams[1], K. Borkowski[1], W. Blair[2], P. Ghavamian[3], K. Long[4], R. Sankrit[5]

[1]North Carolina State Univ., [2]Johns Hopkins, [3]Towson Univ., [4]STScI, [5]USRA.
9:00 AM - 6:30 PM

Fast shock waves like those in young supernova remnants put some fraction of their energy into fast particles, and another fraction into magnetic field. These fractions are not well determined typically, because synchrotron emission from relativistic electrons depends on roughly the product of the two, while the shock energy density depends on gas density and shock speed. Shock speeds can be difficult to determine from thermal X-ray spectra, as electrons and ions may have different temperatures, and significant energy may be lost to the fast particles. Most importantly, accurate thermal-gas densities are often unknown, or only roughly known from X-ray emission measures. All these quantities may vary at different locations in a supernova remnant. We present new determinations of gas densities at various points around the periphery of Kepler's supernova remnant, from modeling Spitzer IRS spectra from shock-heated dust. In combination with shock velocities from proper motions, radio brightnesses, and magnetic-field determinations from X-ray synchrotron morphology, we can then estimate the fractions of shock energy in relativistic electrons and in magnetic field, at different points around the remnant periphery. Furthermore, X-ray synchrotron emission visible around much of the periphery allows the determination of maximum electron energies. We present spatially resolved estimates of these quantities and discuss their significance for theoretical models of shock acceleration.

239.21 – **A Search for X-ray Counterparts to Candidate Radio Supernova Remnants in the Galaxy NGC 4258**

Caleb Grimes[1], T. Pannuti[1], S. Laine[2]

[1]Morehead State University, [2]Caltech.
9:00 AM - 6:30 PM

We present a search for X-ray counterparts to known candidate radio supernova remnants (SNRs) in the nearby spiral galaxy NGC 4258. This galaxy features an enhanced rate of star formation compared to normal spirals: numerous discrete radio sources - including the candidate radio SNRs - were identified by a survey conducted by Hyman et al. (2001) at 6cm and 20cm: the radio luminosities of several of these sources as calculated by Hyman et al. 2001 exceed the radio luminosity of the Galactic SNR Cassiopeia A. To conduct our search, we have downloaded archival X-ray observations made of this galaxy using the Chandra X-ray Observatory: the superior angular resolution attained by Chandra (approximately one arcsecond) is essential for identifying X-ray counterparts to the candidate radio SNRs with significant positional confidence. Results from our analysis have identified two possible X-ray binary sources associated (within 2.5 arcseconds) with highly luminous candidate radio SNRs identified by Hyman et al. 2001. We have analyzed the properties of analogous extragalactic X-ray binary systems with candidate radio SNR counterparts -- namely MF16 and X-7 in NGC 6946 and M81 respectively -- as well as the Galactic X-ray binary/radio SNR system SS433/W50 to provide a context for these systems found in NGC 4258. We have also searched for other candidate X-ray SNRs based on their soft X-ray spectra sources coincident with regions of H-alpha emission in the galaxy NGC 4258. Results will be presented and discussed.

239.22 – **The Iron Peak Elements in Tycho's Supernova Remnant**

Kristoffer A. Eriksen[1], J. P. Hughes[1], J. Colgan[2], C. J. Fontes[2], M. C. Witthoeft[3], C. Badenes[4], P. P. Plucinsky[5], P. Slane[5], R. K. Smith[5]

[1]Rutgers University, [2]Los Alamos National Laboratory, [3]NASA/GSFC, [4]University of Pittsburgh, [5]Harvard-Smithsonian, CfA.
9:00 AM - 6:30 PM

For the non-equilibrium, ionizing (NEI) conditions present in the X-ray gas of young supernova remnants, the iron peak elements are often observed to be in intermediate charge states whose emission lines are not adequately represented in the current generation of plasma codes. We report on our progress in generating with modern atomic physics codes the data necessary to model accurately the NEI X-ray spectra of these ions. We will compare newly calculated spectra against deep Chandra and Suzaku observations of Tycho's supernova remnant, allowing for the first time a reliable measurement of the X-ray emitting mass of iron, as well as other less abundant iron peak elements (Mn, Cr, and Ni).

239.23 – **A Survey of Supernova Remnants detected by Fermi-LAT**

John W. Hewitt[1], Fermi LAT Collaboration

[1]*NASA/GSFC.*
9:00 AM - 6:30 PM

The Fermi Gamma-ray Space Telescope has firmly identified GeV emission from more than a dozen supernova remnants (SNRs) in its first years of operation. Long thought to be capable of supplying the high energy cosmic rays in the Galaxy, SNR shocks are ideal sites to study cosmic-ray acceleration. Here we review the SNRs detected by Fermi-LAT, and discuss their properties. The population of detected remnants spans a large range of ages and environments, allowing for a comparative study of acceleration efficiency. The inclusion of gamma-ray data in multi-wavelength models improves our general understanding of these SNRs, constraining physical parameters including the magnetic field, gas density and energetics.

240 – Stellar Atmospheres, Winds, and Outflows

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

240.01 – **Variable Geocoronal X-ray Emission from Solar Wind Charge Exchange**

Poppy Martin[1], B. J. Wargelin[1]

[1]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

Solar wind charge exchange (SWCX) X-rays are emitted when highly charged solar wind ions such as O7+ collide with neutral gas. The best known examples of this occur around comets, but SWCX emission also arises in the Earth's tenuous outer atmosphere (exosphere, or geocorona) and throughout the heliosphere as neutral H and He from the interstellar medium flows into the solar system. This geocoronal and heliospheric emission comprises much of the soft X-ray background and is seen in every X-ray observation. Geocoronal emission, although usually weaker than heliospheric emission, arises within a few Earth radii and therefore responds much more quickly (on time scales of less than an hour) to changes in solar wind intensity than the widely distributed heliospheric emission.

We are studying roughly a dozen time periods since the launch of the Chandra X-ray Observatory in 1999 when the flux of O7+ in the solar wind (measured by the Advanced Composition Explorer (ACE) satellite) was at its highest. These gusts of wind usually last only a short time and quickly fade, leading to corresponding abrupt changes in geocoronal SWCX X-ray emission. These changes may or may not be seen by X-ray observatories depending on their line of sight through the magnetosphere. We present here preliminary results of our study of the temporal correlation between solar wind flux and the X-ray background emission measured by Chandra.

240.02 – **Application of Stellar Flare Model to Solar Flares**

Alejandro Nunez[1], R. Osten[2]

[1]*CUNY Hunter College,* [2]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

Solar and stellar flares result from the dynamical rearrangement of magnetic fields, which heats plasma and accelerates particles. Solar flare sizes can be directly measured from space-based observatories, giving insight into the behavior and morphology of the solar magnetic field. With current technology, however, we cannot spatially resolve flares that occur on other stars. Consequently, models have been developed that infer flare sizes using X-ray emission produced by the flare-related plasma heating. One model, the “hydrodynamic method” (HM), considers the potential presence of heating during the decay phase of a flare event, along with cooling of the hot material by conduction and radiation. HM assumes that the flare is a single semi-circular loop and that the X-ray emission from the cooling material in the flare declines as a simple exponential. However, several solar and stellar flare observations suggest that this flux decay occurs in two stages, each described by a separate exponential decay timescale. We applied HM to 257 highly energetic, X-class solar flares to determine whether a one or two-stage exponential decay was a better fit for the decay phase. We compared the two fits using a chi-squared minimization technique and F-tests. Through this analysis we determined that 98% of the solar flares in our sample exhibited a two-stage decay phase. Furthermore, of the flares exhibiting a two-stage decay, the flare sizes inferred from stage two were typically much larger than those from stage one, and we found no correlation between them. Given that we do not normally observe significant increases in solar flare sizes during the decay phase −as implied by our results− the two-stage decay phase in X-class flares may indicate a change in the geometry of the flare region (like the appearance of an “arcade”) thus invalidating the results of HM in such instances.

240.03 – **Line Identifications and Preliminary Synthesis of High-resolution Infrared Spectra of CP and Herbig Ae Stars**

Charles R. Cowley[1], F. Castelli[2], S. Hubrig[3], B. Wolff[4], V. Elkin[5]

[1]*Department of Astronomy, Univ. of Michigan,* [2]*Istituto Nazionale di Astrofisica, Osservatorio Astronomico di Trieste, Italy,* [3]*Leibniz-Institut für Astrophysik Potsdam, Germany,* [4]*European Southern Observatory, Garching bei München, Germany,* [5]*Jeremiah Horrocks Institute of Astrophysics, University of Central Lancashire, United Kingdom.*
9:00 AM - 6:30 PM

We report on surveys of infrared spectra of chemically peculiar and Herbig Ae stars based on CRIRES (Kaufl, et al. SPIE, 5492, 1218 2004). We discuss the magnetic CP stars Gamma Equ and HD 154708, and multiple-phase observations of the Herbig Ae star HD 101412. The Be star HR 4537 and HgMn HR 6620 were also examined. The primary emphasis of the present work is on line identifications primarily in four regions, 1065-1091, 1084-1109,1550-1587, and 2276-2313nm (with order gaps). Observations were reduced with recipes available from the ESO CRIRES data reduction pipeline. Wavelength calibration is determined from daytime ThAr arc lamp exposures. Generally speaking, this is not rich in atomic lines. The strongest features are the Paschen line P6 (1093.81nm), and He I (108.30nm). The latter shows phase variations indicative of a more complex magnetic field than that of a pure dipole. No individual molecular lines were found in these early stars, though CO emission from circumstellar material is likely present in HR 4537 and HD 101412. We used atomic line lists from Kurucz's site (kurucz.harvard.edu) and VALD (http://vald.astro.univie.ac.at/ cf. Kupka et al. 1999, A&AS, 138, 119), supplemented by Outred (J. Phys. Chem. Ref. Data 7, 1, 1978). The following spectra were identified in Gamma Equ: C I, Si I, Ca I, Mg I, II, Cr I, Fe I, Sr II, and Ce III (1584.75nm). The Ap star spectra show broad Zeeman patterns compatible with published models and field strengths. Synthetic calculations used SYNTHE and SYNTHMAG (Piskunov N. E., 1999, in

Astrophys. Space Sci. Library Vol. 243, Solar polarization. Kluwer, p 515). The γ Equ model is from Heiter et al. (2002, A&A, 392, 619). and the line list from VALD.

240.04 – **Mass Loss Rates Inferred From Mid-ir Color Excesses Of Lmc And Smc O Stars**

Derck Massa[1], A. Fullerton[1], D. Lennon[1], R. Prinja[2]

[1]*STScI,* [2]*UCL, United Kingdom.*
9:00 AM - 6:30 PM

We use a combination of VJHK and Spitzer [3.6], [5.8] and [8.0] photometry, to determine IR excesses in a sample of LMC and SMC O stars. This sample is ideal for determining excesses for two reasons: 1) the distances to the stars, and hence their luminosities, are well-determined, and 2) the very small line of sight reddening to the stars minimizes the uncertainties introduced by extinction corrections. Preliminary results give IR excesses much larger than expected from their mass loss rates derived from the Vink et al. (2001) formulae. This is in contrast to previous wind line analyses for many of the LMC stars which suggest mass loss rates much less than the Vink et al. predictions. Together, these results indicate that the winds of the LMC and SMC O stars are strongly structured (clumped). This work is supported by NASA's ADAP.

240.05 – **Modeling Anomalous Absorption Features in the FUV Spectra of Late-B Giants**

William Van Dyke Dixon[1], P. Chayer[1]

[1]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

At optical wavelengths, the brightest member of the globular cluster 47 Tuc is the so-called Bright Star (BS). This early-type giant (B8 III) is a post-AGB star with an effective temperature T_eff = 11,000 K, a surface gravity log g = 2.2, and a metallicity [Fe/H] = -0.76, a value consistent with the cluster mean.

The star's far-ultraviolet (FUV) spectrum is well fit by Kurucz models at wavelengths longer than Lyman β, but at shorter wavelengths it is fainter than the models by nearly an order of magnitude. In particular, a spectrum of the star obtained with the Far Ultraviolet Spectroscopic Explorer (FUSE) shows broad absorption troughs with apparent ionization edges at 995 and 1010 Å and a deep absorption feature at 1072 Å. Using photo-ionization cross sections for the first and second excited states of N I (2Do and 2Po) from the Opacity Project, we can reproduce these features in Kurucz models of the stellar spectrum. Doing so requires a signficant increase in the atmospheric nitrogen abundance relative to that indicated by the ground-state N I features, suggesting that non-LTE effects boost the population of excited-state N I atoms.

The star's FUSE spectrum is similar to those of the Pop. I stars HD 1279 (B7 III) and HD 196519 (B9 III), which bracket it in the spectral sequence. We have successfully reproduced the broad absorption features in both spectra by including N I opacity in the models. We conclude that bound-free transitions of neutral nitrogen represent a signficant opacity source in the FUV spectra of late-B giants.

Presentation of this poster is supported by the STScI Director's Discretionary Research Fund.

240.06 – **Study of AGB Mass Loss Models**

Qian Wang[1], L. Willson[1]

[1]*Iowa State Univ.*.
9:00 AM - 6:30 PM

Stars that have reached the tip of the asymptotic giant branch (AGB) are as large and luminous as they can ever be. The mass loss time scale is shorter than the luminosity evolution time scale for mass loss rates exceeding $5x10^{-6}(M/M_{Sun})$ solar masses/year. At the same time the mass outflow is visible to observers since the column density is high. We are using the Bowen code to test the effects on mass loss rates and atmospheric structure of many stellar parameters, such as metallicity, luminosity and radius (related via mixing length), atmosphere opacity, dust condensation temperature, C/O ratio, driving amplitude, and non-LTE onset density. With this code it is possible to run a very large grid of models and look for the dependence of mass loss rate on stellar parameters and physical processes.

240.07 – **Modeling Dust Around Late-Stage Post-AGB Stars**

Alexa H. Hart[1], J. L. Hora[1], L. Cerrigone[2]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Max-Planck Institut fur Radioastronomie, Germany.*
9:00 AM - 6:30 PM

During the post-AGB phase, intermediate mass stars deposit their outer layers in a dense circumstellar envelope as they sputter on the last of their nuclear fuel. Though the phase lasts only a few thousand years, it is thought to be the time when the asymmetries observed in later-stage Planetary Nebulae develop. We present the results of SED modeling of a sample of late-stage post AGB stars and examine the implications of our results for the dust chemistry and shaping agents active during this phase.

240.08 – **First Visual Orbit for the Prototypical Colliding-wind Binary WR 140**

John D. Monnier[1], M. Zhao[2], E. Pedretti[3], R. Millan-Gabet[4], J. Berger[5], F. Schloerb[6], W. Traub[7], T. ten Brummelaar[8], H. McAlister[8], S. Ridgway[9], N. Turner[8], L. Sturmann[8], J. Sturmann[8], F. Baron[1], A. Tannirkulam[10], S. Kraus[1], P. Williams[11]

[1]*Univ. of Michigan,* [2]*Penn State,* [3]*European Southern Observatory, Germany,* [4]*Caltech, NEXSCI,* [5]*LAOG, France,* [6]*U. Massachusetts, Amherst,* [7]*Jet Propulsion Laboratory, Caltech,* [8]*CHARA, Georgia State University,* [9]*NOAO,* [10]*Center for Micro Finance, The Institute for Financial Management and Research, India,* [11]*nstitute for Astronomy, University of Edinburgh, Royal Observatory, United Kingdom.*
9:00 AM - 6:30 PM

Wolf-Rayet stars represent one of the final stages of massive stellar evolution. Relatively little is known about this short-lived phase and we currently lack reliable mass, distance, and binarity determinations for a representative sample. Here we report the first visual orbit for WR 140 (=HD193793), a WC7+O5 binary system known for its periodic dust production episodes triggered by intense colliding winds near periastron passage. The IOTA and CHARA interferometers resolved the pair of stars in each year from 2003--2009, covering most of the highly-eccentric, 7.9~year orbit. Combining our results with the recent improved double-line spectroscopic orbit of Fahed et al. (2011), we can estimate the distance to WR 140 with about 2% error and estimate component masses with about 4% error. Our precision orbit yields key parameters with uncertainties about 6 times smaller than previous work and paves the way for detailed modeling of the system. Our newly measured flux ratios at the near-infrared H and Ks bands allow an SED decomposition and analysis of the component evolutionary states.

240.09 – **The Time Evolution of Eta Carinae's Colliding Winds**

Theodore R. Gull[1], T. I. Madura[2], J. H. Groh[2], M. F. Corcoran[3]

[1]*NASA/GSFC,* [2]*MPIR, Germany,* [3]*CRESST/GSFC.*
9:00 AM - 6:30 PM

We report new HST/STIS observations that map the high-ionization forbidden line emission in the inner arcsecond of Eta Car, the first that fully image the extended wind-wind interaction region of the massive colliding wind binary. These observations were obtained after the 2009.0 periastron at orbital phases 0.084, 0.163, and 0.323 of the 5.54-year spectroscopic cycle. We analyze the variations in brightness and morphology of the emission, and find that blue-shifted emission (-400 to -200 km/s is symmetric and elongated along the northeast-southwest axis, while the red-shifted emission (+100 to +200 km/s) is asymmetric and extends to the north-northwest. Comparison to synthetic images generated from a 3-D dynamical model strengthens the 3-D orbital orientation found by Madura et al. (2011), with an inclination $i = 138$ deg, argument of periapsis $\omega = 270$ deg, and an orbital axis that is aligned at the same PA on the sky as the symmetry axis of the Homunculus, 312 deg. We discuss the potential that these and future mappings have for constraining the stellar parameters of the companion star and the long-term variability of the system.

240.10 – **X-ray Spectra and Variation of the Reflection Nebula of Eta Carinae**

Kenji Hamaguchi[1], M. F. Corcoran[2], Eta Carinae Team

[1]*NASA's GSFC & UMBC,* [2]*NASA's GSFC & USRA.*
9:00 AM - 6:30 PM

The X-ray observing campaign of the wind-wind colliding (WWC) binary system, Eta Carinae, targeted at its periastron passage in 2003, discovered extended X-ray emission from the bipolar nebula around the star during X-ray minimum (Corcoran et al. 2004, ApJ). The X-ray spectrum showed a strong fluorescent iron line at 6.4 keV, which was suggested to originate in emission from the central star, absorbed and re-emitted by the bipolar nebula. The X-ray emission would be one of the clearest examples of a reflection component, in which both the emitting source and reflector are clearly identified.

We launched another focused campaign of X-ray observations for Eta Car during its 2009 periastron passage. We again observed the X-ray reflection nebula during the X-ray faintest phase. A Chandra spectrum generated from multiple exposures confirmed strong emission lines at ~1.8 and 1.4 keV. The spectrum also showed smaller photo-electric absorption than that in 2003, which is similar to a recent NH decrease of direct emission from Eta Carinae. We dis

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241 – Instrumentation: Space Missions

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

241.01 – **Pixel-based CTE Correction of ACS/WFC: Modifications To The ACS Calibration Pipeline (CALACS)**

Linda J. Smith[1], J. Anderson[1], A. Armstrong[1], R. Avila[1], L. Bedin[1], M. Chiaberge[1], M. Davis[1], B. Ferguson[1], A. Fruchter[1], D. Golimowski[1], N. Grogin[1], W. Hack[1], P. L. Lim[1], R. Lucas[1], A. Maybhate[1], M. McMaster[1], S. Ogaz[1], A. Suchkov[2], L. Ubeda[1]

[1]*Space Telescope Science Institute,* [2]*Johns Hopkins University.*
9:00 AM - 6:30 PM

The Advanced Camera for Surveys (ACS) was installed on the Hubble Space Telescope (HST) nearly ten years ago. Over the last decade, continuous exposure to the harsh radiation environment has degraded the charge transfer efficiency (CTE) of the CCDs. The worsening CTE impacts the science that can be obtained by altering the photometric, astrometric and morphological characteristics of sources, particularly those farthest from the readout amplifiers. To ameliorate these effects, Anderson & Bedin (2010, PASP, 122, 1035) developed a pixel-based empirical approach to correcting ACS data by characterizing the CTE profiles of trails behind warm pixels in dark exposures.

The success of this technique means that it is now possible to correct full-frame ACS/WFC images for CTE degradation in the standard data calibration and reduction pipeline CALACS. Over the past year, the ACS team at STScI has developed, refined and tested the new software. The details of this work are described in separate posters. The new code is more effective at low flux levels (< 50 electrons) than the original Anderson & Bedin code, and employs a more accurate time and temperature dependence for CTE.

The new CALACS includes the automatic removal of low-level bias stripes (produced by the post-repair ACS electronics) and pixel-based CTE correction. In addition to the standard cosmic ray corrected, flat-fielded and drizzled data products (crj, flt and drz files) there are three new equivalent files (crc, flc and drc) which contain the CTE-corrected data products. The user community will be able to choose whether to use the standard or CTE-corrected products.

241.02 – **Pixel-based CTE Correction Of ACS/WFC: Column Dependency**

Sara Ogaz[1], J. Anderson[1], A. Maybhate[1], L. Smith[1], ACS Team

[1]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

In 2010 Anderson and Bedin (2010, PASP, 122, 1035) created an algorithm to correct the charge transfer efficiency losses in the Wide Field Channel (WFC) of the Advanced Camera for Surveys (ACS). This algorithm has since been put into a new version of the reduction and calibration pipeline, CALACS. One possible improvement to the current code is to apply a column to column dependency of the CTE levels. We have measured the value of the CTE trails in each column using the overscan region of multiple flat field images. The first few pixels of the overscan contain a trail produced by the flux pixels on the edge of the image. As these flux pixels are read out they pass every trap present in the column, making their trail an accurate reflection of the number of traps in that column. For WFC chip 2 we have found 64% of trail values fall within +/- 10% of the average, and 93% fall within +/- 20%. These column specific measurements have been incorporated into the new version of CALACS.

241.03 – **Pixel-based CTE Correction of ACS/WFC: CTE Time And Temperature Dependence**

Leonardo Ubeda[1], J. Anderson[1], ACS Team

[1]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

We perform a comprehensive and detailed study of the evolution of the effect of charge transfer efficiency (CTE) of the Wide-Field Channel of the Advanced Camera for Surveys (ACS). The study is based on the profiles of warm pixels in all the dark frames ever produced by ACS between 2002 and 2011. We apply the pixel-based empirical approach by Anderson & Bedin (2010, PASP, 122, 1035) which restores flux, position and shape of sources in the original images. We demonstrate that this image-restoration process properly accounts for the time and temperature dependence for CTE in ACS, and that it works for all epochs: the original setting when the camera was operated at -77 ºC and also on the post-SM4 data obtained with the current temperature set at -81 ºC. We also demonstrate that the code has been successfully integrated in the ACS calibration and reduction pipeline CALACS.

241.04 – **Pixel-based CTE Correction of ACS/WFC: New Constraints from Short Darks**

Jay Anderson[1], ACS Team

[1]*STScI.*
9:00 AM - 6:30 PM

The original Anderson & Bedin (2010) pixel-based correction for imperfect charge-transfer efficiency (CTE) in HST's ACS was based on a study of Warm Pixels (WPs) in a series of 1000s dark exposures. WPs with more than about 25 electrons were sufficiently isolated in these images that we could examine and model their trails. However, WPs with fewer electrons than this were more plentiful and suffered from significant crowding. To remedy this, we have taken a series of shorter dark exposures: 30s, 100s, and 339s. These supplemental exposures have two benefits. The first is that in the shorter exposures, 10 electron WPs are more sparse and their trails can be measured in isolation. The second benefit is that we can now get a handle on the absolute CTE losses, since the long-dark exposures can be used to accurately predict how many counts the WPs in the short-dark exposures should see. Any missing counts are a reflection of imperfect CTE. This new absolute handle on the CTE losses allows us to probe CTE even for very low charge packets. We find that CTE losses reach a nearly pathological level for charge packets with fewer than 20 electrons. Most ACS observations have backgrounds that are higher than this, so this does not have a large impact on science. Nevertheless, understanding CTE losses at all charge-packet levels is still important, as biases and darks often have low backgrounds. We note that these WP-based approaches to understanding CTE losses could be used in laboratory studies, as well. At present, many laboratory studies focus on Iron-55 sources, which all have 1620 electrons. Astronomical sources of interest are often fainter than this. By varying the dark exposure time, a wide diversity of WP intensities can be generated and cross-checked.

241.05 – **Pixel-based CTE Correction of ACS/WFC: Potential Benefits from Charge Injection**

David A. Golimowski[1], J. Anderson[1], L. J. Smith[1], J. MacKenty[1], E. Cheng[2], A. Waczynski[3], E. Graham[3], E. Wilson[3], L. Mazzuca[3], M. Loose[4]

[1]*Space Telescope Science Institute,* [2]*Conceptual Analytics LLC,* [3]*NASA Goddard Space Flight Center,* [4]*Markury Scientific Inc.*
9:00 AM - 6:30 PM

The implementation of charge injection (CI) as a means of mitigating charge transfer inefficiency (CTI) in HST's WFC3/UVIS channel has inspired us to study the possible use of CI with HST's ACS/WFC channel and its potential benefit to subsequent CTI correction with the pixel-based algorithm of Anderson & Bedin. We have achieved substantial CTI mitigation in the laboratory using both continuous and discrete line injection modes of CI with an irradiated engineering-grade ACS/WFC CCD. Although the mitigation and noise characteristics of the line injection are favorable for scientific use in the regime of very low natural sky background (< 10 e-/pix) as is prevalent in WFC3/UVIS exposures, line injection is not practical for the vast majority of ACS/WFC science exposures, which have backgrounds of 40-150 e-/pix. Moreover, the short average release time of ACS/WFC charge traps precludes uniform mitigation in the interline regions and significantly complicates science data analysis. On the other hand, a continuous injection (or "flood") of several hundred electrons with noise ≤ 7 e- would uniformly limit CTI to 20% at all signal levels and pixel locations while only minimally affecting the signal-to-noise ratios of the sources. Such CTI losses could subsequently be corrected by the pixel-based algorithm to better than 5%. If such CI is achievable, it could become the default operating mode for ACS exposures in future observing cycles.

241.06 – **Pixel-Based CTE Correction Of ACS/WFC: Extended Sources**

Ray A. Lucas[1], N. A. Grogin[1], M. Chiaberge[1], ACS Group

[1]*STScI.*
9:00 AM - 6:30 PM

The effect of CTE grows worse with time due to radiation damage to on-orbit CCD detectors. It affects objects the worst in the y-direction, along columns, though also to a much lesser degree across rows in the x-direction, and its effect is greatest when farthest from the relevant amplifier. It affects objects across a wide range of magnitudes, but the effects are worst in fainter sources, and affect photometry, astrometry, and the morphological shapes of sources. Using our new pixel-based CTE corrections, we perform an initial exploration of the effect primarily as seen along columns in the y-direction of the WFC at a recent epoch. Though not the primary focus in this poster, we ultimately aim to expand this study to examine more time-dependent effects on extended sources over the lifetime of the detector, as well as addressing the additional instantaneous effects of an object's x-position (minor effect) and especially its y-position (much larger effect) on the detector at a given epoch.

241.07 – **Pixel-based CTE Correction Of ACS/WFC: Effects On Signal To Noise Ratio**

Roberto J. Avila[1], A. Fruchter[1], J. Anderson[1], ACS Team

[1]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

The Advanced Camera for Surveys (ACS) team at STScI has tested a new pixel-based empirical correction (Anderson & Bedin, PASP, 122, 1035) software for CTE effects that occur due to the high radiation environment of space. Here we present a study of how this algorithm changes the characteristics of the signal to noise ratio and photometry of point sources. In order to eliminate unknown variables we use simulated images where we can control the noise and CTE characteristics. We explore a parameter space that includes background, object brightness, and position on the chip. Overall we find that while the signal in a source is largely recovered, the noise in the background is amplified. This effect is more noticeable in low background levels and in regions far from the readout amplifiers. Extra care must be taken when measuring the sky background because the use of some common measurement schemes can introduce systematic effects in the photometry. We also show how a simple noise mitigation routine helps in reducing these effects, although they are not completely eliminated.

241.08 – **Characterization and Mitigation of ACS/WFC Signal-Dependent Bias Shift**

Norman A. Grogin[1], A. Suchkov[2], D. Golimowski[1], M. Loose[3]

[1]*Space Telescope Science Institute,* [2]*Johns Hopkins University,* [3]*Markury Scientific, Inc..*
9:00 AM - 6:30 PM

Subsequent to HST Servicing Mission 4 in 2009, the four read-out amplifiers of the Advanced Camera for Surveys Wide Field Channel (ACS/WFC) exhibit similar but distinct shifts in their pixel-to-pixel bias levels that are signal-dependent. For zero-second bias frames, the bias shift manifests as a smooth gradient across each of the ACS/WFC image quadrants. The peak-to-peak amplitude of the fluctuation for bias frames is large (14-20 e-) but highly repeatable, so the effect is cleanly removed with calibration super-biases.

The signal-dependent component of the bias

shift is linearly proportional to the pixel signal and decays nearly linearly over the course of several hundred serial transfers. Typically the amplitude of the signal-dependent shift is far below the pixel-to-pixel ACS/WFC read noise of 4e-. However, ACS/WFC fields containing many consecutive high-intensity pixels (e.g., Saturn) can develop excess bias-level distortions of 30e- or more, potentially compromising science with these images. The amplitude of the bias shift is electronically well determined, and thus near-perfectly removable from ACS/WFC images.

We present the formula for modeling and removing the effect, using a small number of parameters fit independently to bias frames and to images of Saturn recorded through each ACS/WFC amplifier. The ACS Instrument Team is currently considering the incorporation of this correction into the automated image reduction pipeline, or at least the distribution of this code to the community as a stand-alone in the STSDAS software suite.

241.09 – **WFC3 UVIS Detector: Improved Flat Fields**

Tomas Dahlen[1], J. Mack[1], E. Sabbi[1], WFC3 Team

[1]*STScI.*
9:00 AM - 6:30 PM

We describe the improved flat field calibration for a set of UVIS broad-band filters that were delivered to MAST in August 2011. The total change peak-to-peak with respect to the previous pipeline flats ranges from 3.6% to 5.6%, increasing with wavelength. The flat-fields previously used in the pipeline were obtained during ground testing and contained a large reflection ghost (or flare) that affected ~40% of the field. A simplified geometric model of the internal light reflections has been used to remove the flare from the ground flats. Residual low-frequency structures caused by differences in the ground-based and in-flight optical paths were then computed using photometry of Omega Centauri, observed at various roll angles and with large dithered steps. Furthermore, photometry in a range of apertures has been used to study the UVIS PSF in detail. For radii smaller than 0.4" (10 pixels) the PSF is strongly dependent on both the detector position and on the telescope focus at the time of observation. Therefore, the new pipeline flat fields have been normalized to "infinite" aperture by applying local aperture corrections to 10 pixels, making them more generally applicable.

241.10 – **The Wide Field Camera 3 (WFC3) UVIS and IR Photometric Calibration.**

Susana E. Deustua[1], WFC3 Team

[1]*Space Telescope Science Institute.*
9:00 AM - 6:30 PM

I will present and discuss results from the WFC3 Cycle 17 and Cycle 18 phototmetric calibration program, including zeropoints, throughput and stability of the UVIS and IR channels. I also describe the Cycle 19 programs to monitor photometric behavior and develop a flux calibration ladder.

241.11 – **The Wide Field Camera 3 (WFC3) Cycle 19 Calibration Plan.**

Elena Sabbi[1], J. MacKenty[1], S. E. Deustua[1], WFC3 Team

[1]*STScI.*
9:00 AM - 6:30 PM

The WFC3 Cycle 19 calibration program has been designed to measure and monitor the behavior of both the UVIS and IR channels. The program was formulated with the actual usage of WFC3 in mind, to provide the best calibration data for the approved scientific programs. During the cycle the WFC3 team is using a total of 125 external and 1497 internal, divided in 28 different programs, which can be divided in 6 categories: Monitor, Photometry, Spectroscopy, Detectors, Flatfields and Image Quality. Further details about the WFC3 CY19 Calibration Plan can be found at http://www.stsci.edu /hst/wfc3/calibration/CY19

241.12 – **Status and Calibration of the HST Wide Field Camera 3**

John W. MacKenty[1], WFC3 Team

[1]*STScI.*
9:00 AM - 6:30 PM

The Wide Field Camera 3 on the Hubble Space Telescope continues to perform at or better than specification. The team at STScI provides both user support and instrument calibration with several major improvements in calibration over that past year. This poster describes the improvements to slitless spectroscopic mode calibrations, calibration of the stability and linearity of the infrared detector, and the availability of pixel history tracking to support identification and partial correction of image persistence in infrared images. Companion papers at the meeting discuss CCD Charge Transfer Efficiency changes and mitigation, improved flat fields and photometric zero points, early investigations using the recently commissioned spatial scan mode, and the HST Cycle 19 Calibration plan for WFC3.

241.13 – **Charge Transfer Efficiency and Charge Injection in the HST/WFC3 UVIS Detectors**

Sylvia M. Baggett[1], K. Noeske[1], J. Anderson[1], J. Biretta[1], T. Borders[1], H. Bushouse[1], V. Khozhurina-Platais[1], J. MacKenty[1], L. Petro[1], WFC3 Team

[1]*STScI.*
9:00 AM - 6:30 PM

Devices in low-earth orbit are particularly susceptible to the cumulative effects of radiation damage and the Hubble Space Telescope Wide Field Camera 3 (HST/WFC3) UVIS detectors, installed on HST in May 2009, are no exception. Such damage not only generates new hot pixels but also degrades the charge transfer efficiency (CTE), causing a loss in source flux due to charge traps as well as a systematic shift in the object centroid as the trapped charge is slowly released during readout. Based on an analysis of both internal and external monitoring data, we provide an overview of the consequences of the more than 2.5 years of radiation damage to the WFC3 CCD cameras. The advantages and disadvantages of available mitigation options are discussed, including use of the WFC3 charge injection capability, a mode now available to observers, and the status of an empirical correction similar to the one adopted for the HST Advanced Camera for Surveys (ACS).

241.14 – **SSET: Spatially-scanned Spectra of Exoplanet Transits**

Peter R. McCullough[1], Z. K. Berta[2], A. W. Howard[3], J. W. MacKenty[1], WFC3 Team

[1]*STScI,* [2]*CfA,* [3]*UCB.*
9:00 AM - 6:30 PM

Spatial scanning is expected to have some advantages over staring-mode observations with the HST WFC3 instrument, especially for very bright stars, i.e. those that intrinsically can provide the highest sensitivity observations. We analyze 1.1-1.7 micron spectra of a transit of the super-Earth GJ1214b obtained 2011-4-18 during re-commissioning of a technique for spatially scanning the Hubble Space Telescope. These are the first data of this type obtained with the HST instrument WFC3. Results are directly compared to staring-mode observations with the same instrument of the same target by Berta et al. (2011). We also describe a case study of the sub-Neptune-sized planet HD 97658b in terms of proposed observations and what they may reveal of that planet. We also summarize publicly-available descriptions of additional HST programs that use the spatial-scanning technique (Table 1).

Table 1

HST program, Title, Investigators, Scanned Targets

12181 The Atmospheric Structure of Giant Hot Exoplanets, Deming, L. D. et al., HD 209458 and HD 189733

12325 Photometry with Spatial Scans, MacKenty, J. W., & McCullough, P. R., GJ1214

12336 Scan Enabled Photometry, MacKenty, J. W., McCullough, P. R., & Deustua, S., Vega and other calibration stars

12449 Atmospheric Composition of the ExoNeptune HAT-P-11, Deming, L. D., et al., HAT-P-11

12473 An Optical Transmission Spectral Survey of hot-Jupiter Exoplanetary Atmospheres, Sing, D. K. et al., WASP-31, HAT-P-1

12495 Near-IR Spectroscopy of the Hottest Known Exoplanet, WASP-33b, Deming, L. D. et al., WASP-33

12679 Luminosity-Distance Standards from Gaia and HST, Riess, A., et al., Milky Way Cepheids

12713 Spatial Scanned L-flat Validation Pathfinder, McCullough and MacKenty, nearly identical double stars

241.15 – **An Update on the Performance of the Space Telescope Imaging Spectrograph**

K. Azalee Bostroem[1], A. Aloisi[1], R. C. Bohlin[1], C. Cox[1], R. Diaz[1], W. Dixon[1], J. Duval[1], J. Ely[1], E. Mason[1], R. Osten[1], C. Proffitt[1], P. Sonnentrucker[1], M. A. Wolfe[1], B. York[1], W. Zheng[2]

[1]*Space Telescope Science Institute,* [2]*Johns Hopkins University.*
9:00 AM - 6:30 PM

The Space Telescope Imaging Spectrograph was installed during Hubble Servicing Mission 2 in 1997 and operated until a malfunction in 2004. It was repaired during Servicing Mission 4 (SM4) in 2009, and has successfully operated since then. Many of the characteristics of the instrument have continued to evolve over time with the same trends seen in Cycle 17. We present here an update on its current performance based on the latest Cycle 18 and 19 calibration observations. Specifically we will provide updates on the sensitivity of all STIS modes, the evolution of the echelle blaze function, the flat fields and dark rates of each detector, and characteristics of the CCD detector including read noise, spurious charge, number of hot pixels, and charge transfer efficiency.

241.16 – **Updated Status and Performance for the Cosmic Origins Spectrograph**

Justin Ely[1], A. Aloisi[1], K. Bostroem[1], P. Hodge[1], D. Massa[1], C. Oliveira[1], R. Osten[1], S. Penton[2], C. Proffitt[1], D. Sahnow[3], W. Zheng[3]

[1]*Space Telescope Science Institute,* [2]*CASA, University of Colorado at Boulder,* [3]*The Johns Hopkins University.*
9:00 AM - 6:30 PM

The Cosmic Origins Spectrograph (COS) was installed on the Hubble Space Telescope (HST) in May 2009. COS is designed to perform high-sensitivity, medium- and low-resolution spectroscopy of astronomical objects in the 1150-3200 Å wavelength range. COS significantly enhances the spectroscopic capabilities of HST at ultraviolet wavelengths, providing observers with unparalleled opportunities for observing faint sources of ultraviolet light. Provided here is an update on some aspects of detector performance and current calibration projects from Cycle 18 along with new additions for the upcoming Cycle 19. Included are discussions on the detector dark current, time dependent sensitivity, and recent and upcoming additions to CalCOS. We also present initial characteristics of a new G130M/1222 central wavelength setting for the Far-Ultraviolet (FUV) channel. This new mode, available in Cycle 20, provides a resolving power of R>10,000 from 1065 to 1365 angstroms while placing the damaging flux of the LyA airglow line in the gap between detector segments A and B.

241.17 – **Maximizing COS Detector Lifetime: Gain Sag and the Selection of a New Detector Lifetime Position for the FUV Channel on the Cosmic Origins Spectrograph**

David J. Sahnow[1], A. Aloisi[2], P. E. Hodge[2], E. Mason[2], D. Massa[2], C. Oliveira[2], R. Osten[2], S. N. Osterman[3], S. V. Penton[3], C. Proffitt[2]

[1]*Johns Hopkins University,* [2]*Space Telescope Science Institute,* [3]*University of Colorado.*
9:00 AM - 6:30 PM

The Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope (HST) uses a two-segment, large-format microchannel plate (MCP) detector with a cross delay line anode in its Far Ultraviolet (FUV) channel. Local gain variations in the MCPs, due to the much greater illumination of some areas of the detector, is now evident, and complicates the extraction of the science data. These effects will become more severe in the future as the detector exposure increases. Therefore, we are now preparing to

move the spectra to an alternate position by the summer of 2012 in order to extend the lifetime of the detector. We will discuss mitigation strategies implemented both onboard HST and in the calcos calibration pipeline to improve the quality of the spectra collected at the current position, and describe the tests conducted in order to identify and characterize several alternate lifetime positions. Finally, we will discuss our plans for the initial calibration program at the next location.

241.18 – **Geocoronal Lyman Alpha Observations with COS**

Thomas B. Ake[1]

[1]*Space Telescope Science Institute/Computer Sciences Corporation.*
9:00 AM - 6:30 PM

The time-tagged mode of the Cosmic Origins Spectrograph (COS) provides a convenient method of studying the orbital variation of geocoronal Lyman-alpha emission at the altitude of HST. We have analyzed G130M blank sky exposures from scheduled STIS parallels and observations for which the target acquisition failed. We supplement these with observations of WD standard stars from flat field and sensitivity monitoring programs where the stellar Lyα profile can be modeled and its contribution to the geocoronal emission removed. Data were corrected for time-dependent sensitivity changes and gain sag. The measurements have been fit by an analytical model based on the orbital position of HST and the angle between the target and the Earth as seen from HST. The Lyα emission varies from less than 2 kR for a target observed at orbit midnight to 37 kR for one observed at the bright Earth limb at orbit noon. A long-term trend of increasing flux is evident, consistent with solar Lyα measurements by SOLSTICE on SORCE as the next solar maximum is approached. We expect the irradiance at solar maximum to be at least 50-55 kR. This level still should not trigger local count rate violations for the FUV detector, but will accelerate gain sag of the microchannel plates in the regions where Lyα falls.

241.19 – **Announcing A New HST+COS Central Wavelength: G130M/1222**

Steven V. Penton[1], S. N. Osterman[1], K. France[1], C. Oliveira[2], D. J. Sahnow[3]

[1]*University of Colorado,* [2]*Space Telescope Science Institute,* [3]*Johns Hopkins University.*
9:00 AM - 6:30 PM

The combination of the Hubble Space Telescope (HST) and the Cosmic Origins Spectrograph (COS) has been shown to be sensitive down to 912Å. However, the existing G140L/1280 and G130M central wavelengths (1055 and 1096) that sample below 1150Å are low-resolution (R < 5,000). In early HST Cycle 19 observations (PID#12505), we calibrated a new G130M central wavelength that is focused to maximize resolution in the astrophysically important 1070-1140Å region. Early observations indicate a resolution of R > 12,000 over the segment-B bandpass (1064-1207Å) and R> 10,000 over the segment-A bandpass (1222-1368Å). Raytrace estimates indicate a potential peak of R > 17,000 at 1140Å. This mode intentionally places Geocoronal Lyman-alpha on the FUV detector gap. This extends the lifetime of the COS FUV detectors as it removes the dominate source of unwanted detector-damaging light. In this presentation, we review the G130M/1022 calibration processes and results, as well as present ERO observations of the AGN HE0238-1904 and its high ionization intrinsic absorbers. This new central wavelength will be available to HST observers in Cycle 20.

241.20 – **Dark Ages Radio Explorer Instrument Verification Program: Antenna Test Results**

Abhirup Datta[1], R. Bradley[2], J. O. Burns[1], J. Lazio[3], J. Bauman[4]

[1]*University of Colorado,* [2]*National Radio Astronomy Observatory,* [3]*Jet Propulsion Laboratory,* [4]*NASA Ames Research Center.*
9:00 AM - 6:30 PM

Observations of the HI 21 cm transition line promises to be an important probe into the cosmic Dark Ages and Epoch of Reionization. The Dark Ages Radio Explorer (DARE) is designed to measure the sky-averaged 21-cm signal from this cosmic age using a single radiometer operating between 40-120 MHz (redshifts z=11-35). DARE will orbit the Moon for a mission lifetime of ≤ 3 years and take data above the lunar far side, where it is shielded from the Earth's intense interference. The science objectives of DARE include formation of first stars, first accreting black holes, beginning of reionization and end of the Dark Ages. The science instrument is composed of a three-element radiometer, including electrically-short, tapered, bi-conical dipole antennas, a receiver, and a digital spectrometer. Although the TRL (Technology Readiness Level) of the individual components of DARE instrument is high, the overall instrument TRL is low. One of the main aim of the entire DARE team is to advance the instrument TRL. In this work we mainly focus on the development work for DARE Antenna. We will present the initial test results of a prototype DARE antenna, fabricated in NRAO. Some CST simulations using the actual DARE experiment set up have also been performed. In future, we plan to perform extensive tests to characterize the beam pattern and spectral response of the prototype DARE instrument design. In order to utilize the anechoic chamber available at NRAO, we will use a half-scale version of the DARE antenna (120-200 MHz). The full-scale version of the DARE antenna (40-120 MHz) along with the final version of the DARE receiver will be used for outdoor tests in the low-RFI environment of Western Australia. We will also present the initial software development for analyzing the test results from the prototype DARE antenna and receiver.

241.21 – **JMAPS Observations Planning Simulator**

Viktor Zubko[1], G. S. Hennessy[1], B. N. Dorland[1]

[1]*United States Naval Observatory.*
9:00 AM - 6:30 PM

The Joint Milli-Arcsecond Pathfinder Survey (JMAPS) cataloging mission will provide position, proper motion, parallax, photometry and spectrophotometry for bright stars with much greater accuracy over existing catalogs. In order to get most from the mission, a JMAPS observations planning simulator (JOPS) is under development in the United States Naval Observatory. The reported version of JOPS is capable of simulating JMAPS orbital, boresight and field of view (FOV) motions in various observing modes subject to pointing, slew, battery, and other mission constraints. JOPS generates a system of reference cells that cover the entire sky without gaps and serve as a base for observations planning and accounting. To estimate the efficiency of observations, the simulator calculates various metric properties such as the number of FOV hits per cell and the number of cells inside the FOV, and respective distribution functions. Finally, JOPS computes a detailed list of observability of sky cells as a function of the year's week, which can be used for both long-term and short-term planning of JMAPS observations. One of the main applications of the simulator will be finding optimal time allocations for observing modes to meet the mission requirements.

241.22 – **Status of the James Webb Space Telescope Observatory**

Mark Clampin[1], C. Bowers[1]

[1]*NASA's GSFC.*
9:00 AM - 6:30 PM

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 last year. Polishing of the JWST telescope, optical train is complete with 18 primary mirror segments, the secondary mirror, tertiary and fine steering mirror all complete and gold coated. The sunshield engineering articles are in production with the first layer 3 membrane complete and undergoing testing. We review the expected scientific performance of the observatory in the context of initial performance measurements of flight hardware, and performance projections from integrated system models of the observatory.

241.23 – **Progress in the Fabrication and Testing of Telescope Mirrors for The James Webb Space Telescope**

Charles W. Bowers[1], M. Clampin[1], L. Feinberg[1], R. Keski-Kuha[1], A. McKay[2], D. Chaney[3], B. Gallagher[3], K. Ha[1]

[1]*NASA's GSFC,* [2]*Northrup-Grumman Aerospace Systems,* [3]*Ball Aerospace & Technologies Corporation.*
9:00 AM - 6:30 PM

The telescope of the James Webb Space Telescope (JWST) is an f/20, three mirror anastigmat design, passively cooled (40K) in an L2 orbit. The design provides diffraction limited performance (Strehl ≥ 0.8) at λ=2μm. To fit within the launch vehicle envelope (Arianne V), the 6.6 meter primary mirror and the secondary mirror support structure are folded for launch, then deployed and aligned in space. The primary mirror is composed of 18 individual, 1.3 meter (flat:flat) hexagonal segments, each adjustable in seven degrees of freedom (six rigid body + radius of curvature) provided by a set of high precision actuators. The actuated secondary mirror (~0.74m) is similarly positioned in six degrees of rigid body motion. The ~.70x.51m, fixed tertiary and ~0.17m, flat fine steering mirror complete the telescope mirror complement. The telescope is supported by a composite structure optimized for performance at cryogenic temperatures.

All telescope mirrors are made of Be with substantial lightweighting (21kg for each 1.3M primary segment). Additional Be mounting and supporting structure for the high precision (~10nm steps) actuators are attached to the primary segments and secondary mirror. All mirrors undergo a process of thermal stabilization to reduce stress. An extensive series of interferometric measurements guide each step of the polishing process. Final polishing must account for any deformation between the ambient temperature of polishing and the cryogenic, operational temperature. This is accomplished by producing highly precise, cryo deformation target maps of each surface which are incorporated into the final polishing cycle.

All flight mirrors have now completed polishing, coating with protected Au and final cryo testing, and the telescope is on track to meet all system requirements. We here review the measured performance of the component mirrors and the predicted performance of the flight telescope.

241.24 – **Cryo-Vacuum Testing of the Integrated Science Instrument Module for the James Webb Space Telescope**

Randy A. Kimble[1], P. S. Davila[1], M. P. Drury[2], S. D. Glazer[1], J. R. Krom[2], R. A. Lundquist[1], S. D. Mann[3], D. B. McGuffey[1], R. L. Perry[4], D. D. Ramey[4]

[1]NASA's GSFC, [2]NASA's GSFC/SIGMA, [3]NASA's GSFC/Hammers, [4]NASA's GSFC/SGT.

9:00 AM - 6:30 PM

With delivery of the science instruments for the James Webb Space Telescope (JWST) to Goddard Space Flight Center (GSFC) expected in 2012, current plans call for the first cryo-vacuum test of the Integrated Science Instrument Module (ISIM) to be carried out at GSFC in early 2013. Plans are well underway for conducting this ambitious test, which will perform critical verifications of a number of optical, thermal, and operational requirements of the ISIM hardware, at its deep cryogenic operating temperature. We describe here the facilities, goals, methods, and timeline for this important Integration & Test milestone in the JWST program.

241.25 – **NIRSpec, the Near-IR Multi-Object Spectrograph for JWST**

Pierre Ferruit[1], S. Arribas[2], T. Beck[3], S. Birkmann[1], T. Boeker[1], A. Bunker[4], S. Charlot[5], G. De Marchi[1], M. Franx[6], G. Giardino[1], G. Giardino[1], G. Giardino[1], R. Maiolino[7], H. Moseley[8], P. Jakobsen[9], J. Muzerolle[3], K. Pontoppidan[3], B. Rauscher[8], M. Regan[3], H. W. Rix[10], M. Sirianni[1], D. Soderblom[3], J. Tumlinson[3], J. Valenti[3], C. Willott[11]

[1]ESTEC, Netherlands, [2]DAMIR, Spain, [3]STScI, [4]Oxford University, United Kingdom, [5]IAP, France, [6]Leiden University, Netherlands, [7]INAF, Italy, [8]NASA/GSFC, [9]DARK, Denmark, [10]MPIA, Germany, [11]Herzberg Institute of Astrophysics, Canada.

9:00 AM - 6:30 PM

NIRSpec will be the first slit-based astronomical multi-object spectrograph to fly in space, and is designed to provide spectra of faint objects over the near-infrared 1.0 - 5.0 micron wavelength range at spectral resolutions of R=100, R=1000 and R=2700. The instrument's all-reflective wide-field optics, together with its novel MEMS-based programmable micro-shutter array slit selection device and its large format low-noise HgCdTe detector arrays, combine to allow simultaneous observations of >100 objects within a 3.4 x 3.5 arcmin field of view with unprecedented sensitivity. A selectable 3 x 3 arcsec Integral Field Unit and five fixed slits are also available for detailed spectroscopic studies of single objects. NIRSpec is being built for the European Space Agency (ESA) by EADS Astrium as part of ESA's contribution to the JWST mission. The NIRSpec micro-shutter and detector arrays are provided by NASA/GSFC.

In this poster we present the instrument status and the first results of its ground calibration campaign under cryogenic conditions.

241.26 – **The Extra-Zodiacal Explorer (EZE)**

Matthew A. Greenhouse[1], S. W. Benson[2], D. J. Fixsen[1], J. P. Gardner[1], J. W. Kruk[1], H. A. Thronson[1]

[1]NASA's GSFC, [2]NASA's GRC.

9:00 AM - 6:30 PM

We describe a mission architecture study designed to substantially increase the potential science performance of the NASA SMD Astrophysics Explorer Program for all AO offerors working within the near-UV to far-infrared spectrum. We have demonstrated that augmentation of Falcon 9 Explorer launch services with a Solar Electric Propulsion (SEP) stage can deliver a 700 kg science observatory payload to an extra-Zodiacal orbit. This new capability enables up to 10X increased photometric sensitivity and 150X increased observing speed relative to a Sun-Earth L2 or Earth-trailing orbit with no increase in telescope aperture. All enabling SEP stage technologies for this launch service augmentation have reached sufficient readiness (TRL-6) for Explorer Program application in conjunction with the Falcon 9. We demonstrate that enabling Astrophysics Explorers to reach extra-zodiacal orbit will allow this small payload program to rival the science performance of much larger long development time systems; thus, providing a means to realize major science objectives while increasing the SMD Astrophysics portfolio diversity and resiliency to external budget pressure. The SEP technology employed in this study has applicability to SMD Planetary competed missions and aligns with NASA in-space propulsion technology road map objectives and associated flight demonstration planning.

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242 – Supernovae

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

242.02 – **COS Observations of SN1987A**

Richard McCray[1], K. France[1], R. P. Kirshner[2], SAINTS Collaboration

[1]Univ. of Colorado, [2]Harvard-Smithsonian CFA.

9:00 AM - 6:30 PM

We present the most sensitive ultraviolet observations of Supernova 1987A to date. Imaging spectroscopy from the Hubble Space Telescope-Cosmic Origins Spectrograph shows many narrow (v ~ 300 km/s) emission lines from the circumstellar ring, broad (v ~ 10 - 20 × 10^3 km/s) emission lines from the reverse shock, and ultraviolet continuum emission. The high signal-to-noise (> 40 per resolution element) broad Ly α emission is excited by soft X-ray and EUV heating of mostly neutral gas in the circumstellar ring and outer supernova debris. The ultraviolet continuum at > 1350 A can be explained by H I 2-photon (2s 2S1/2 - 1s 2S1/2) emission from the same region. We confirm our earlier, tentative detection of N V 1240 emission from the reverse shock and we present the first detections of broad He II 1640, C IV 1550, and N IV] 1486 emission lines from the reverse shock. The helium abundance in the high velocity material is He/H = 0.14 ± 0.06. The N V/H line ratio requires partial ion-electron equilibration (Te/Tp ≈ 0.14 - 0.35). We find that the N/C abundance ratio in the gas crossing the reverse shock is significantly higher than that in the circumstellar ring, a result we attribute to continued CNO processing in the supernova progenitor subsequent to the expulsion of the circumstellar ring.

242.03 – **Properties Of Super-luminous Supernovae: Insights From Observations, Light Curve Modeling And Simulations**

Emmanouil Chatzopoulos[1], J. C. Wheeler[1], J. Vinko[2], D. S. P. Dearborn[3], S. M. Couch[4]

[1]University of Texas, Austin, [2]University of Szeged, Hungary, [3]Lawrence Livermore National Lab, [4]University of Chicago.

9:00 AM - 6:30 PM

The current sample of Super Luminous Supernova is heterogeneous. Some show strong emission lines of hydrogen in their spectra close to maximum light (SN 2006gy, SN 2006tf, SN 2008fz, SN 2008iy) and typically belong to the Type IIn subclass; some show hydrogen in later phases and a linear decline of the light curve (LC) expressed in magnitudes (SN 2008es). Others may show no hydrogen at all (SN 2005ap). Careful analysis of the light curve shape and duration as well as the spectral characteristics helps us constrain the properties of the progenitor stars and their Circumstellar Matter envelopes. For this, we present semi-analytical models of Type II SN light curves powered by a variety of luminosity inputs, including forward and reverse shock luminosity due to the interaction between the SN ejecta and the CSM. The effects of Gray diffusion are incorporated with an approach similar to that proposed by Arnett (1980, 1982) in the case of radioactive decays of Ni-56 and Co-56. We find that ejecta-CSM interaction provides a better fit to the LCs of most of those events.CS shock power input can produce the LCs of Type IIn SNe in terms of duration, shape and decline rate, depending on the properties of the CSM envelope. We conclude that the observed LC variety of Type II L, Type IIn and of the SLSNe is likely to be a byproduct of the large range of conditions relevant to significant ejecta-CSM interaction as a power source. Finally, we outline preliminary results from multi-dimensional radiation hydrodynamics simulations of SN ejecta-CSM interaction and Pair-Instability Supernovae (PISN) performed with the latest version of the FLASH code in order to investigate the details

of the physics that give rise to some Super-Luminous Supernovae.

242.04 – **An Archival Search for Radio Transients in M51**

Kate Alexander[1], A. M. Soderberg[2], L. Chomiuk[2]

[1]Brown University, [2]Harvard-Smithsonian Center for Astrophysics.

9:00 AM - 6:30 PM

We present results from the first search for radio transients in a nearby galaxy, M51 (NGC 5194). The search was conducted using archival data from the Very Large Array spanning a period of nearly 30 years. Most data were taken at a frequency of 4.9 GHz, with supplemental observations at other frequencies. Each epoch is 10-20 minutes in duration and epochs are irregularly spaced, making us sensitive to transients on a wide range of timescales. This image depth allows us to detect transients at the distance of M51 down to a luminosity of ~10e25 erg/s/Hz. As our search includes data collected during the extensive monitoring of SN 1994I by Weiler et al. in the years following its discovery, we also present an independent analysis of a subset of radio observations of this important type Ic supernova. We find that the data is well-fit by a synchrotron self-absorption model and estimate a pre-explosion mass loss rate of ~2-5 x 10e-5 solar masses per year, which is consistent with a Wolf-Rayet progenitor for the SN.

This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

242.05 – **Can We Detect Clumpiness in Supernova Ejecta?**

K. Tabetha Hole[1], C. Boom[2]

[1]ETSU, [2]Weber State U..

9:00 AM - 6:30 PM

Polarization is detected at early times for all types of supernovae, indicating that all such

systems are, or quickly become, asymmetric. Spectropolarimetric observations also show that the asymmetry varies in both magnitude and orientation for different elements in the ejecta. One explanation for these observations is that local chemical inhomogeneities (called clumps) exist in the ejecta above the region where the continuum forms. To examine the effects of clumpiness on observations, I will present results of a comparison between a fast, flexible, approximate semi-analytic code for modeling polarized line radiative transfer within three-dimensional inhomogeneous rapidly expanding atmospheres; and VLT spectropolarimetric observations of SN2006X.

242.07 – **Supernova Remnant Progenitor Masses in M31**

Zachary Jennings[1], B. F. Williams[1], J. W. Murphy[2], J. J. Dalcanton[1]

[1]*University of Washington,* [2]*Princeton University.*

9:00 AM - 6:30 PM

We age-date the stellar populations surrounding ~60 supernova remnants (SNR) in M31 and estimate the masses of their progenitors. Measurement of physical properties of core-collapse supernovae progenitors is an inherently difficult observational task. In the past it has been necessary to have archival Hubble Space Telescope (HST) images of the star prior to explosion to make accurate measurements of its age and mass, leading to only a handful of definite measurements. We instead employ color-magnitude diagram (CMD) fitting to measure the star formation history of the population, from which we determine a characteristic age. Application of stellar evolution models then leads to a progenitor mass estimate. Our method has the tremendous advantage of not requiring direct imaging of the progenitor, allowing us to use the large quantity of archival HST data to perform this CMD analysis on cataloged SNR. We present the results of this analysis on the stellar populations surrounding ~60 SNR in the galaxy M31. We analyze the resulting distribution of masses and discuss implications relating to massive star evolution and the initial mass function.

242.08 – **Supernovae In The Subaru Deep Field: The Rate And Delay-time Distribution Of Type Ia Supernovae Out To Redshift 2**

Or Graur[1], SDF SN team

[1]*Tel-Aviv University, Israel.*

9:00 AM - 6:30 PM

The Type Ia supernova (SN Ia) rate, when compared to the cosmic star formation history (SFH), can be used to derive the delay-time distribution (DTD; the hypothetical SN Ia rate versus time following a brief burst of star formation) of SNe Ia, which can distinguish among progenitor models. We present the results of a supernova (SN) survey in the Subaru Deep Field (SDF). Over a period of 3 years, we have observed the SDF on four independent epochs with Suprime-Cam on the Subaru 8.2-m telescope, with two nights of exposure per epoch, in the *R*, *i*′and *z*′ bands. We have discovered 150 SNe out to redshift $z \approx 2$. Our final sample includes 28 SNe Ia in the range $1.0 < z < 1.5$ and 10 in the range $1.5 < z < 2.0$. As our survey is largely insensitive to core-collapse SNe (CC SNe) at $z > 1$, most of the events found in this range are likely SNe Ia. Based on this sample, we find that the SN Ia rate evolution levels off at $1.0 < z < 2.0$, but shows no sign of declining. Combining our SN Ia rate measurements and those from the literature, and comparing to a wide range of possible SFHs, the best-fitting DTD (with a reduced $\chi^2 = 0.7$) is a power law of the form $\Psi(t) \propto t^{\beta}$, with index $\beta = -1.1 \pm 0.1$ (statistical) ± 0.17 (systematic). By combining the contribution from CC SNe, based on the wide range of SFHs, with that from SNe Ia, calculated with the best-fitting DTD, we predict that the mean present-day cosmic iron abundance is in the range $Z_{Fe} = (0.09\text{-}0.37)\ Z_{Fe,\odot}$.

242.09 – **Absolute-Magnitude Distributions of Supernovae**

Robert Jenkins[1], J. Wright[2], D. Richardson[2], L. Maddox[3]

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The absolute-magnitude distributions of supernovae (SNe) are presented. These distributions are separated by supernova type so that we can see what absolute magnitude ranges should be expected for each type. The bulk of the data used in this study are taken from the Asiago Supernova Catalog. There are currently about 5700 supernovae in the catalog. This is nearly a three-fold increase over the last time this study was conducted. Host galaxy extinction is accounted for statistically in the distributions. The samples presented here are limited to supernovae within a radius of approximately 94 Mpc (distance modulus = 35). This helps to reduce the bias against dim supernovae. We find the mean absolute magnitudes for normal SNe Ia and SNe IIn to be brighter than MB = -19, while the mean absolute magnitudes for SNe IIb, IIL and IIP are dimmer than MB = -18.

242.10 – **Type Ia Supernova Color Curves: Disentangling Intrinsic Variations from Dust**

Samia Bouzid[1], C. McCully[1], S. Jha[1]

[1]*Rutgers University.*

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Type Ia supernovae (SNe Ia) are important cosmological tools based on their use as "standard candles": as objects of similar intrinsic luminosity, their variations in apparent brightness are a reliable indication of relative distance. The more accurately we can measure and correct for variations in SN Ia brightness, the more precisely we can determine cosmological distances and place constraints on cosmological parameters including the Hubble constant and the nature of dark energy.

Corrections for dust along the line of sight to the SN are usually based on its reddening effect; however, recent studies have shown that the relationship between extinction and reddening of SN light curves does not match canonical values for standard, Milky Way-like dust. It is likely that color variations intrinsic to the SNe themselves are confounding our ability to independently determine the dust extinction and reddening.

Using ground-based photometry of several hundred SNe from the published literature, we present an analysis that attempts to disentangle the effects of dust and intrinsic color variations by looking at the time dependence of SNe Ia colors, controlling for light curve shape properties by empirically matching similar objects.

242.11 – **Comparing Type Ia Supernovae from Targeted and Wide Field Surveys**

Robert Quimby[1], F. Yuan[2], C. Akerlof[3], J. C. Wheeler[4], M. S. Warren[5]

[1]*IPMU, Japan,* [2]*Australian National University, Australia,* [3]*University of Michigan,* [4]*University of Texas,* [5]*LANL.*

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We compare the Type Ia Supernovae discovered by ROTSE-IIIb to other surveys including the targeted LOSS and wide field SDSS-II surveys. Although modest in size, the ROTSE-IIIb sample is both non-targeted and spectroscopically complete--and thus unique among supernova surveys. About half of the Type Ia supernovae found by ROTSE reside in dwarf galaxies, which is a much higher fraction than reported in other wide-field surveys that also use image subtraction techniques to remove the blinding glare of bright host galaxies. We calculate the volumetric SN Ia rate from the ROTSE-IIIb sample. The results, while of low significance, are supportive of a higher overall SN Ia rate than has previously been published, which combined with the surplus in dwarf hosts may indicate under counting of the contribution from low-luminosity hosts in prior works. We also compare the SN Ia luminosity function reported by LOSS to the volume limited SDSS-II sample and find the later lacking in low-luminosity events.

242.12 – **Nearby Supernova Factory Observations of 2007if-like SNe Ia**

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We present optical photometry and time-series spectroscopy of five type Ia supernovae discovered by the Nearby Supernova Factory (SNfactory), which are spectroscopic matches to the candidate super-Chandrasekhar-mass event SN 2003fg. These supernovae are also overluminous ($-19.5 < M_V < -20$) and, like the similar SN 2007if, the velocity of the Si II 6355 absorption minimum is consistent with being constant in time from the earliest available measurements to as late as two weeks after maximum light. We interpret the velocity plateau as evidence for a reverse-shock shell in the ejecta formed by interaction at early times with a compact envelope of surrounding material, as might be expected for SN events resulting from the mergers of two white dwarfs. We use the bolometric light curves and velocity evolution of these events to estimate important parameters of the progenitor systems, including 56Ni mass, total progenitor mass, and masses of shells and surrounding carbon/oxygen envelopes. We discuss the relationship of these events to classical 1991T-like SNe Ia and to other candidate super-Chandrasekhar-mass SNe Ia, and compare the mass distribution to that expected from population synthesis of merging white dwarf binary systems.

242.13 – **A Study of the Wolf-Rayet Population of M101 using the Hubble Space Telescope.**

Joanne Bibby[1], M. Shara[1]

[1]*American Museum of Natural History.*

9:00 AM - 6:30 PM

How do massive stars end their lives? This is one of the most fundamental questions in massive stellar evolution yet it remains unanswered. Theory suggests that stars with an initial mass above ~20Msun end their lives as Type Ib/c core-collapse supernovae (ccSNe), however to date there is no direct observational confirmation. One candidate progenitor of Type Ibc ccSNe are evolved massive stars called Wolf Rayet (WR) stars but broad-band imaging has, so far, failed to identify the WR progenitor of ~10 Type Ibc ccSNe. Does this indicate a binary progenitor or are the broad-band images simply not suitable? I present ongoing work searching for WR stars in several nearby star-forming galaxies, focusing on M101. We have obtained narrow-band high spatial resolution HST/WFC3 imaging, and I will show images of WR stars that are not detected in broad-band images. Moreover, analysis of the central M101 field shows a WR rich galaxy hosting over ~1000 WR stars, a significant fraction of which we do not detect in our ground based surveys.

242.14 – **Supernova Spectropolarimetry with the VLT**

J. Craig Wheeler[1], D. Baade[2], A. Clocchiatti[3], P. Hoeflich[4], J. Maund[5], F. Patat[2], J.

Quinn[3], J. Spyromilio[2], L. Wang[6], P. Zelaya[3]
[1]*Univ. of Texas,* [2]*ESO, Germany,* [3]*Pontificia Universidad Catolica de Chile, Chile,* [4]*Florida State University,* [5]*Queen's University Belfast, Ireland,* [6]*Texas A&M.*
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Supernova explosions are intrinsically three-dimensional phenomena with significant departures from spherical symmetry. We summarize the evidence derived from spectropolarimetry that has established several key results: Virtually all supernovae are significantly aspherical near maximum light; core-collapse supernovae behave differently than thermonuclear (Type Ia) supernovae; the asphericity of core-collapse supernovae is more pronounced in the inner layers, showing that the explosion process is strongly aspherical; core-collapse supernovae tend to establish a preferred direction of asymmetry; and the asphericity is stronger in the outer layers of thermonuclear supernovae, providing constraints on the burning process. An axially symmetric geometry can explain many basic features of core-collapse supernovae, but significant departures from axial symmetry are needed to explain most events. We introduce a spectropolarimetry type to classify the range of behavior observed in polarized supernovae. Understanding asymmetries in supernovae is important for phenomena as diverse as the origins of gamma-ray bursts and the cosmological applications of Type Ia supernovae in studies of the dynamics of the universe. Spectropolarimetry of core-collapse supernovae suggests segregation of ejected chemical elements and the presence of buried "jets." The combination of spectroscopic and spectropolarimetric indicators suggests a single geometric configuration for normal Type Ia, with some of the diversity of observed properties arising from orientation effects.

242.15 – **Photometric Analysis Of Sn2011dn**

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[1]*California State University San Marcos,* [2]*San Diego State University.*
9:00 AM - 6:30 PM

Type Ia supernovae (SNe Ia) have been extensively studied and used as standard candles. There are different sub types of SNe Ia, that include over-luminous (SN 1991T-like), under-luminous (SN 1991bg-like), and peculiar (e.g., SN2000cx, SN 2002cx, SN 2005hk). These sub-types reveal themselves through spectral and photometric differences from "normal" SNe Ia. Here we report on the collection and reduction of photometric data of supernova SN 2011dn during the course of a 41 day period, which started a few days before maximum. A pre-maximum spectrum provided a tentative SN 1991T-like classification (Koff et al. 2011) for this event, from which a broad, slowly declining light-curve with low Delta M_15(B) was anticipated. However, preliminary reduction (i.e., without the benefit of galaxy subtraction) and analysis of our light curves suggest that SN 2011dn did not confirm this prediction. In this poster we will discuss the peculiar nature of SN2011dn and compare it to other SNe Ia that have exhibited similar characteristics. We acknowledge support from the National Science Foundation (grants AST-1009571 and AST-0850564) under which this work was carried out.

242.16 – **The Influence of Central Density on the Brightness of Type Ia Supernovae**

Alan Calder[1], B. K. Krueger[1], A. P. Jackson[2], D. M. Townsley[3], E. F. Brown[4], F. X. Timmes[5]
[1]*SUNY Stony Brook,* [2]*NRL,* [3]*University of Alabama,* [4]*Michigan State University,* [5]*Arizona State University.*
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We present details of a statistical study investigating the role of the central density of the progenitor white dwarf on the brightness of a Type Ia supernova. We present results from a suite of two-dimensional simulations varying the central density at flame ignition. We find that the production of Fe-group material does not significantly change with increased progenitor central density, but that the mass of stable Fe-group isotopes is tightly correlated with central density. The result is a decrease in the production of ^{56}Ni, which we attribute to a higher rate of neutronization occurring at higher density. We present details of our models including the distribution of ^{56}Ni and quantify trends of ^{56}Ni production. We also relate the variations in central density to the age of the host galaxy stellar population through the main-sequence lifetime and the white dwarf cooling time, which is the elapsed time between the formation of the white dwarf and the onset of accretion. This density-age relationship, along with our results, allows us to obtain the observed relationship between the age of the host galaxy and the average brightness of an event.

This work was supported by NASA under grant No. NNX09AD19G and utilized resources at the New York Center for Computational Sciences at Stony Brook University/Brookhaven National Laboratory, which is supported by the U.S. Department of Energy under Contract No. DE-AC02-98CH10886 and by the State of New York.

242.17 – **The 2-year Checkup On 10 SNe IIn Discovered By Spitzer To Exhibit Late-time (>100 Day) IR Emission**

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9:00 AM - 6:30 PM

Two years ago, a warm Spitzer survey of sixty-eight SNe IIn identified between the years 1998-2008 discovered 10 events with unreported late-time infrared (IR) excesses, in some cases more than 5 years post-explosion. These data nearly double the database of existing mid-IR observations of SNe IIn and offer important clues regarding the SN circumstellar environment, explosion mechanism, and even progenitor system. From this single epoch of data, along with ground-based optical data, we determined the likely origin of the mid-IR emission to be pre-existing dust continuously heated by optical emission generated by ongoing circumstellar interaction between the forward shock and circumstellar medium. Furthermore, an emerging trend suggests that these SNe decline at ~1000--2000 days post-discovery once the forward shock overruns the dust shell. Here we present initial results from a follow-up warm Spitzer survey of the 10 SNe. These data allow us to constrain our models, including both the size of the circumstellar dust shell and progenitor mass-loss properties.

242.18 – **Photometric Monitoring of SN 2011dh**

Michelle E. Spencer[1], M. D. Joner[1], C. D. Laney[1], E. Stoker[1]
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9:00 AM - 6:30 PM

We present BVRI light curves of SN 2011dh located in the nearby, nearly face-on spiral galaxy M51. The data were secured using the 0.9 m telescope at the West Mountain Observatory. The data span approximately 100 days with the first observations being before maximum light. The shapes of the light curves are well defined and the time of maximum light is well established. Standard Johnson-Cousins filters were utilized for all of the observations and several nights from this data set were standardized using selections of Landolt standards. SN 2011dh has been classified as Type IIb core-collapse supernova.

We would like to thank the Brigham Young University College of Physical and Mathematical Sciences for continued support of mentored student research at the West Mountain Observatory. Partial support for this project was derived from NSF grant AST #0618209.

242.19 – **228 Type Ia Supernovae from the ESSENCE Survey**

Gautham Narayan[1], A. Rest[2], C. Aguilera[3], A. C. Becker[4], S. Blondin[5], P. Challis[6], A. Clocchiatti[7], R. Covarrubias[4], G. Damke[8], T. M. Davis[9], A. V. Filippenko[10], R. J. Foley[6], M. Ganeshalingam[10], A. Garg[1], P. M. Garnavich[11], M. Hicken[1], S. W. Jha[12], R. P. Kirshner[1], K. Krisciunas[13], B. Leibundgut[14], W. Li[10], K. Mandel[1], T. Matheson[15], A. Miceli[4], G. Miknaitis[16], G. Pignata[17], J. L. Prieto[18], A. G. Riess[19], B. P. Schmidt[20], J. Silverman[10], R. C. Smith[15], J. Sollerman[21], J. Spyromilio[14], C. W. Stubbs[1], N. B. Suntzeff[13], J. L. Tonry[22], B. E. Tucker[20], S. Vikas[23], W. M. Wood-Vasey[23], A. Zenteno[24]
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We present final light curves for 228 Type Ia Supernovae (SNIa) from the ESSENCE Survey. These objects were observed between 2002 and 2008 with the CTIO 4m telescope. We detail our efforts to improve our internal photometric consistency and absolute photometric calibration to the 1% level. We have obtained multi-band host galaxy photometry and spectroscopy where possible for a large fraction of our objects. We present a Hubble diagram for our six year sample combined with complementary SNIa measurements from several surveys.

242.20 – **Analysis of Late-time Light Curves of Type IIB, Ib and Ic Supernovae**

Vincent Johnson[1], J. Wheeler[1], A. Clocchiatti[2]
[1]*Department of Astronomy, University of Texas at Austin,* [2]*Pontificia Universidad Catolica de Chile, Chile.*
9:00 AM - 6:30 PM

The shape of the light curve of radioactive-powered core-collapse supernovae constrains the ejecta mass, nickel mass, and kinetic energy by the brightness and diffusion time for a given opacity and observed expansion velocity. Late-time light curves give constraints on the same parameters, given the gamma-ray opacity. Previous work has shown that the principal light curve peaks for SN IIb with small amounts of hydrogen and for hydrogen/helium-deficient SN Ib/c are often rather similar near maximum light, suggesting similar ejecta masses and kinetic energies, but that late-time light curves show a wide dispersion, suggesting a dispersion in ejecta masses and kinetic energies. It was also shown that SN IIb and SN Ib/c can have very similar late-time light curves, but different ejecta velocities demanding significantly different ejecta masses and kinetic energies. We revisit these topics by collecting and analyzing well-sampled single color and quasi-bolometric light curves from the literature.

242.21 – **Turbulent Combustion in Type Ia Supernovae**

Aaron P. Jackson[1], D. M. Townsley[2], A. C. Calder[1]

[1]*Stony Brook University,* [2]*The University of Alabama.*

9:00 AM - 6:30 PM

Despite their use as standardizable candles that led to the (Nobel-prize winning) discovery of the accelerating Universe, we still do not understand the mechanism by which type Ia supernovae explode. Some of the most successful proposed scenarios involve a centrally-ignited deflagration of a massive C-O white dwarf. Due to vigorous convection prior to ignition and the subsequent fluid instabilities that develop, the details of turbulent combustion are critically important to capture the evolution of the explosion. The relatively slow and extremely non-linear progression of the deflagration phase provides a link between expected ignition conditions and gross properties of the supernova. In order to provide a physical understanding of how variations in the properties of the white dwarf (or host galaxy) affect the explosion outcome, numerical investigations must be performed in 3D with a detailed treatment of turbulence-flame interaction (TFI). We present initial results from incorporating a new treatment of TFI in 3D simulations of type Ia supernovae.

This work was supported in part by NASA under grant No. NNX09AD19G. The author's present address is at the Naval Research Laboratory.

242.22 – **Applications of Gaussian Processes to Supernova Data**

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[1]*LBNL,* [2]*LBNL, UC Berkeley.*

9:00 AM - 6:30 PM

We demonstrate the use of Gaussian processes in problems relevant to Type Ia supernova cosmology experiments and the analysis of supernovae in general. Gaussian processes are a powerful statistical approach that generalizes the concept of probability distributions over random variables to functions. Nonlinear regression, smoothing, and machine classification problems are target applications of Gaussian processes. Areas where Gaussian processes may be an interesting solution in Type Ia supernova cosmology are: principled construction of spectroscopic surface templates, robust extraction of spectral feature measurements, and light curve fitting/modeling. We describe our high-performance computer framework that scales to data sets of interest to current and near-term cosmology experiments, describe computational challenges in the implementation (and their resolution), and show example results using data from the Nearby Supernova Factory and simulations from the Dark Energy Survey.

242.23 – **Daily Photometry Of SN 2011fe, The Youngest Type Ia Supernova, From *u* Through K-band**

Federica Bianco[1], B. Fulton[1], B. Dilday[1], D. Sand[1], Y. Jeon[2], J. Parrent[1], M. Graham[1], D. Howell[1], M. Im[2], K. Maguire[3], M. Sullivan[3], P. Nugent[4], PTF collaboration

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9:00 AM - 6:30 PM

SN 2011fe is the youngest SNIa ever discovered, identified in the PTF images only hours after explosion. The LCOGT network followed this SN with daily cadence in optical (ugri) bands, with high cadence observations in g and i, while UKIRT collected daily cadence near infrared data. Here we analyze daily photometry, including a bolometric lightcurve, of SN 2011fe starting a day after explosion through 15 days after maximum.

242.24 – **UBVRI Optical monitoring of Supernova 2011fe in Pinwheel Galaxy with the 1.3-meter Robotically Controlled Telescope**

Andrew Gott[1], L. Strolger[1], RCT Consortium

[1]*Western Kentucky University.*

9:00 AM - 6:30 PM

Supernova 2011fe may prove to be one of the most important supernovae in recent history. At a distance of only 20 Mega-lightyears, SN 2011fe is the nearest event of its type to have occurred in the last 40 years. It was bright enough to be discovered within a day of explosion, and has been continuously followed by a network of amateur and professional astronomers around the globe, collect a rich multi-wavelength dataset on this important event. I will present our contribution to this dataset collected using the 1.3-meter Robotically Controlled Telescope (RCT) using a standard UBVRI filterset. I will also present the photometric transformation calibrations derived for the RCT in the process of this photometric followup campaign.

242.25 – **X-ray Heating Of The Ejecta Of Supernova 1987A**

George Sonneborn[1], J. Larsson[2], C. Fransson[2], R. Kirshner[3], P. Challis[3], R. McCray[4], SAINTS Collaboration

[1]*NASA's GSFC,* [2]*Stockholm University, Sweden,* [3]*Harvard University,* [4]*University of Colorado.*

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Analysis of Hubble Space Telescope B and R band images from 1994 to 2009 show that the optical luminosity of SN 1987A has transitioned from being powered by radioactive decay of 44Ti to energy deposited by X-rays produced as the ejecta interacts with the surrounding material (Larsson et al 2011, Nature, 474, 484). The B and R band flux from the densest, central parts of the ejecta followed the expected exponential decline until 2001 (about day 5000) when the flux in these bands started increasing, more than doubling by the end of 2009. This increase is the result of heat deposited by X-rays from the shock interaction of the fast-moving outer ejecta with the inner circumstellar ring. In time, the X-rays will penetrate farther into the ejecta, enabling us to analyse the structure and chemistry of the vanished star.

242.26 – **Spontaneous Formation of Detonations by Turbulent Flames in Thermonuclear Supernovae**

Alexei Y. Poludnenko[1], E. S. Oran[1]

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9:00 AM - 6:30 PM

Presently, the scenario best capable of explaining the observational properties of "normal" type Ia supernovae (SNIa), which are of primary importance for cosmology, is the delayed-detonation model. This model postulates that a subsonic thermonuclear deflagration, which originates close to the center of a Chandrasekhar-mass white dwarf (WD) in a single-degenerate binary system, transitions to a supersonic detonation (deflagration-to-detonation transition, or DDT) during the later stages of the explosion. Modern large-scale multidimensional simulations of SNIa cannot capture the DDT process and, thus, are forced to make two crucial assumptions, namely (a) that DDT does occur at some point, and (b) when and where it occurs. Significant progress has been made over the years in elucidating the nature of DDT in terrestrial confined systems with walls, obstacles, or pre-existing shocks. It remains unclear, however, whether and how a detonation can form in an unpressurized, unconfined system such as the interior of a WD. Here we show, through first-principles numerical simulations, that sufficiently fast, but subsonic, turbulent flames in such unconfined environments are inherently susceptible to DDT. The associated mechanism is based on the unsteady evolution of turbulent flames faster than the Chapman-Jouguet deflagrations and is qualitatively different from the traditionally suggested gradient (spontaneous reaction wave) model. It also does not require the formation of distributed flames. The proposed mechanism predicts the DDT density in SNIa to be $\sim 10^7$ g/cm^3, in agreement with the values previously found to give the best match with observations. This DDT mechanism opens the possibility for eliminating the transition density as a free parameter and, thus, for developing fully self-consistent global multidimensional SNIa models.

This work was supported in part by the Naval Research Laboratory, the Air Force Office of Scientific Research, and by the Department of Defense High Performance Computing Modernization Program.

242.27 – **The Enhancement Rate of SN Ia Events in Globular Clusters**

Joel Norman Bregman[1]

[1]*Univ. of Michigan.*

9:00 AM - 6:30 PM

In globular clusters, dynamical evolution produce luminous X-ray emitting binaries at a rate hundreds of times greater than in the field. If globular clusters also produce SN Ia's at a high rate, it would account for most of the SN Ia production in early type galaxies and provide insight into their formation. Here we use archival HST images of nearby galaxies that have hosted a SNIa to examine the rate at which globular clusters produce these events. The location of the SN Ia is registered on an HST image obtained before the event or after the supernova faded. Of the 36 nearby galaxies examined, 21 had sufficiently good data to search for globular cluster hosts. None of the 21 supernova have a definite globular cluster counterpart, although there are some ambiguous cases. This places an upper limit to the enhancement rate of SN Ia production in globular clusters of about 50, which is an order of magnitude lower than the enhancement rate for luminous X-ray binaries. We conclude that globular clusters are not responsible for producing a significant fraction of the SN Ia events in early-type galaxies. We gratefully acknowledge support from NASA grant NNX11AJ55G.

242.28 – **Observations of the Shock Breakout Emission From the Type cIIb**

SN2006el

Camille N. Leibler[1], A. Soderberg[1], M. R. Drout[1]

[1]*Harvard University.*
9:00 AM - 6:30 PM

We report on the photometry of SN2006el, a supernova spectroscopically determined to be a type IIb. SN2006el is unique in that out of the roughly 6000 supernovae known to date, it is one of only a handful to be observed within 24 hours of its initial explosion. We were therefore able to study its early evolution and find evidence for a blue excess for t < 3 days. This blue excess caused by the light from the shock breakout allowed us, in conjunction with theoretical models, to determine the radius of the exploding star and find evidence for a compact progenitor star. This leads us to believe that SN2006el should in fact be classified as a type cIIb.

242.29 – **Fast, Faint, And Massive: Core-collapse Models For Quickly Evolving Supernovae**

Io Kleiser[1], D. Kasen[1]

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9:00 AM - 6:30 PM

Transient surveys have recently discovered several extremely fast-evolving and often faint supernovae. In addition to their unusual light curves, these objects have peculiar spectra that are distinct from those of ordinary supernovae of any type. The explanation most often proposed for these objects involves a small amount of mass and explosion energy (~0.1 solar masses and ~0.1 B, respectively), perhaps from the detonation of a helium shell on a white dwarf in the theoretical ".Ia" model. We generate synthetic spectra and light curves using SEDONA, a Monte Carlo radiative transfer code, and fit them to the data of one of these objects, SN 2010X. Preliminary results suggest that in fact low masses such as in the ".Ia" model have difficulty reproducing certain spectral absorption features. As an alternative, we explore more massive stellar explosions that produce only trace amounts of radioactive material. The resulting light curve is powered almost entirely by the energy from the explosion itself, allowing a core-collapse scenario to fit the short timescales observed. We also test this model against the observations of several other short-lived supernovae and discuss whether they may be produced by similar progenitor situations.

242.30 – **The peculiar fast-fading Type I SN2005ek**

Christopher Jensen[1], A. M. Soderberg[2]

[1]*Harvard University,* [2]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

We present the results of our photometric analysis of the hydrogen-poor supernova SN2005ek. In comparison with other Type I supernovae, SN2005ek fades significantly faster; we derive an e-folding timescale of $\tau \sim 5$ days. We further examine the color evolution of SN2005ek and find that it is generally bluer than standard Type Ia and Type Ibc supernovae. We suggest that SN2005ek may be a new member of the emerging class of rapid-decay, hydrogen-poor supernovae and discuss implications for the progenitor systems of these events. We thank the Harvard College Research Program for its generous funding which enabled this research.

242.31 – **Spectropolarimetric Study of SN 2007sr**

Alejandro Clocchiatti[1], D. Baade[2], P. Hoeflich[3], J. Maund[4], F. Patat[2], J. Quinn[1], L. Wang[5], C. Wheeler[6], P. Zelaya[1]

[1]*Univ. Catolica De Chile, Chile,* [2]*European Sourthen Observatory, Germany,* [3]*Florida State University,* [4]*Dark Energy Cosmology Center, Denmark,* [5]*Texas A&M University,* [6]*Univ. of Texas at Austin.*
9:00 AM - 6:30 PM

We present late time spectropolarimetric observations of SN 2007sr, obtained with the VLT telescope at ESO Paranal Observatory when the object was more than two months after maximum light. SN 2007sr is one of those so called “normal” type Ia SN. It exploded in the Antennae interacting galaxies, and was used to compute a precise distance to them. This was good, since it settled an issue on earlier discrepant measurements. A standard assumption, based on a limited number of not ideally sampled events, is that both continuum and line polarization of Type Ia SN decrease with time as the photosphere recedes into deeper layers and the ejecta becomes more transparent. Yet, SN 2007sr displays very strong line polarization in the Ca II absorption features more than two months after maximum light. The observations prompts us to revisit the incipient conventional wisdom that we are developing on polarimetric properties of Type Ia SNe.

242.32 – **Early Time Bolometric Light curves of Type-II Supernovae Observed by Swift**

Tyler A. Pritchard[1], P. W. A. Roming[2]

[1]*Pennsylvania State University,* [2]*Southwest Research Institute.*
9:00 AM - 6:30 PM

We present early time (~ 0-50 days) bolometric light curves of UV-bright Core Collapse Supernovae observed with the *Swift* UV/Optical Telescope. We generate pseudo-bolometric light curves from *Swift* UV and optical data and examine these by subtype as well as the observed and interpolated UV and IR flux contributions by epoch and bolometric corrections at early times from UV data.

242.33 – **X-ray Emission From Sn Ia 1885a & 1985g?**

Melody M. Packard[1], E. M. Schlegel[2], D. Patnaude[3], S. Katsuda[4], R. Petre[5]

[1]*San Antonio College,* [2]*University of Texas at San Antonio,* [3]*Smithsonian Astrophysical Observatory,* [4]*RIKEN Institute,* [5]*NASA Goddard Space Flight Center.*
9:00 AM - 6:30 PM

X-ray emission is expected from the explosion and subsequent evolution of a Type Ia supernova. The outgoing shock will run into circumstellar material from early phases of the progenitor's evolution and generate X-ray emission from the interaction. To date, Type Ia supernovae have not been convincingly detected as X-ray sources. A number of remnants in the Milky Way are X-ray sources (eg, SN1006, Tycho). The question of when Type Ia supernovae become X-ray-emitting remnants remains open. We analyze and discuss the available Chandra X-ray Observatory data on two old Type Ia supernovae, SN1885A in M31 and SN1986G in NGC 5128 (= Cen A).

242.35 – **Spectroscopic Time-Series of Transients with Light Echoes**

Armin Rest[1], B. Sinnott[2], D. L. Welch[2], F. Bianco[3], J. L. Prieto[4], N. Smith[5], R. J. Foley[6], M. Huber[7], P. Challis[6]

[1]*Space Telescope Science Institute,* [2]*McMaster University, Canada,* [3]*Las Cumbres Observatory Global Telescope Network,* [4]*Princeton University,* [5]*Steward Observatory,* [6]*Harvard-Smithsonian Center for Astrophysics,* [7]*University of Hawaii.*
9:00 AM - 6:30 PM

One as-yet unrealized opportunity provided by light echoes is the ability to obtain a spectroscopic time series of the event and constrain its lightcurve shape. For short events with time-scales on the order of months like supernovae, favorable dust properties and HST-like PSF sizes are required. For long events on the order of years, this technique is only marginally affected by the width of the scattering dust and the PSF-size of the observations. We show case studies of Eta Carinae and Cas A for which this is possible.

242.36 – **SN2010jp: A Jet-Driven Type II Supernova**

Nathan Smith[1]

[1]*U. of Arizona.*
9:00 AM - 6:30 PM

We present photometry and spectroscopy of the peculiar Type II supernova (SN) 2010jp, also named PTF10aaxi. The light curve exhibits a linear decline with a relatively low peak absolute magnitude of only −15.9 (unfiltered), and a low radioactive decay luminosity at late times that suggests a low synthesized nickel mass of M(56Ni)< 0.003 Msun. Spectra of SN2010jp display an unprecedented triple-peaked H-alpha line profile, showing: (1) a narrow central component that suggests shock interaction with a dense circumstellar medium (CSM); (2) high-velocity blue and red emission features centered at −12,600 and +15,400 km/s; and (3) very broad wings extending from −22,000 to +25,000 km s/1. These features persist over multiple epochs during the 100 days after explosion. We propose that this line profile indicates a bipolar jet-driven explosion, with the central component produced by normal SN ejecta and CSM interaction at mid and low latitudes, while the high-velocity bumps and broad line wings arise in a nonrelativistic bipolar jet. Two variations of the jet interpretation seem plausible: (1) A fast jet mixes 56Ni to high velocities in polar zones of the H-rich envelope, or (2) the reverse shock in the jet produces blue and red bumps in Balmer lines when a jet interacts with dense CSM. Jet-driven SNe II are predicted for collapsars resulting from a wide range of initial masses above 25 Msun, especially at sub-solar metallicity. This seems consistent with the SN host environent, which is either an extremely low luminosity dwarf galaxy or the remote parts of an interacting pair of galaxies, and with the apparently low 56Ni mass that may accompany black hole formation. We speculate that the jet survives to produce observable signatures because the star’s H envelope was very low mass.

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243 – AGN, QSO, Blazars II

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

243.01 – **Dust-Driven Winds from Accreting Super-Massive Black Holes Simulated Using Monte Carlo Radiative Transfer**

Nathaniel Roth[1], D. Kasen[1], P. F. Hopkins[1], E. Quataert[1]

[1]*UC Berkeley.*

9:00 AM - 6:30 PM

We use Monte Carlo radiative transfer to construct a simulated snapshot of the radiation pressure force on dusty gas residing within a radius of approximately 10 parsecs from an accreting super-massive black hole. Our snapshot corresponds to the moment that the black hole enters an epoch of accretion after a large amount of gas has been drawn in to the galactic nucleus. We estimate the expected mass-loss rate in the resulting wind as a function of solid angle, as well as the velocity of the ejected gas. We also consider the effects of varying the accretion luminosity, the dust content of the surrounding gas, and the spatial configuration of the gas (informed by hydrodynamic simulations). This allows us to provide a parameterization of the radiation pressure feedback as these inputs are changed, and this parameterization may be incorporated into hydrodynamic simulations of galaxy evolution. Finally, our work allows us to comment on the dynamics of the 'dusty torus' that is invoked to unify observations of active galactic nuclei. This research is supported in part by the Department of Energy Office of Science.

243.02 – **Multi-dimensional Quasar Selection from Optical, Near-IR, and Astrometric Data**

Gordon T. Richards[1], S. S. Mehta[1], C. M. Peters[1], A. D. Myers[2], N. P. Ross[3]

[1]*Drexel Univ.,* [2]*University of Wyoming,* [3]*LBNL.*

9:00 AM - 6:30 PM

In the future, quasar selection will be much more multi-dimensional than it is today. Algorithms will go far beyond simple optical color or variability selection. Instead quasar selection will rely on simultaneous usage of multi-wavelength photometry, variability, and even astrometry. The SDSS Southern Equatorial Stripe (aka Stripe 82) is an ideal proving ground for such future algorithms. Herein we take the first steps in true multi-dimensional analysis by describing an algorithm that uses multi-epoch optical data from the SDSS, near-IR data from UKIDSS, and astrometric information to select quasars (and determine photometric redshifts). We present the resulting catalog and compare our results to existing spectroscopic surveys.

243.03 – **Mean SEDs and Bolometric Corrections for SDSS Selected Quasars**

Coleman M. Krawczyk[1], G. T. Richards[1]

[1]*Drexel University.*

9:00 AM - 6:30 PM

We explore the spectral energy distributions (SEDs) for 121,988 SDSS-selected quasars using mid-IR data from Spitzer, near-IR data from 2MASS and UKIDSS, optical data from SDSS, and UV data from GALEX. We consider the problem of determining bolometric corrections for individual quasars as opposed to the ensemble average. Significant differences can arise due to the fact that even the best observed SEDs have a gap of nearly 2 decades in frequency between the UV and X-ray. By fitting different quasar models in this region we find bolometric corrections can take on a range of values. We particularly consider the dependence of the bolometric correction on the UV luminosity and the properties of the CIV emission line. The latter can be used to distinguish between hard-spectrum radio-quiet quasars and soft-spectrum radio-quiet quasars, which can have very different bolometric corrections for the same UV luminosity and thus different Eddington ratios.

243.04 – **Searching for High-Redshift Obscured Quasars in the Sloan Digital Sky Survey (SDSS) Baryonic Oscillation Spectroscopic Survey (BOSS)**

Rachael Alexandroff[1], M. Strauss[1], N. Zakamska[2], J. Greene[1]

[1]*Princeton University,* [2]*Johns Hopkins.*

9:00 AM - 6:30 PM

Discoveries from Chandra, Spitzer and SDSS have revealed a substantial population of luminous dust-obscured quasars. It is now apparent that quasar demographics based on optically bright objects are missing a substantial fraction of the quasar population; at low redshifts ($z < 0.8$), SDSS studies have shown that of order half of all high-luminosity quasars are obscured. Many obscured quasars have narrow-line regions illuminated by the central engine, and thus are recognized from their emission-line ratios as excited by an accreting black hole.

A search for quasars at $z>1$ with narrow lines from SDSS-I/II turned up high-redshift analogues to Narrow-Line Seyfert 1 galaxies. But BOSS includes substantially lower-luminosity objects at all redshifts. This project is to explore the emission-line width distribution of quasars in BOSS, specifically with the goal of finding examples of obscured quasars at high redshift. Preliminary examination found a population of 207 strong candidates at redshifts $1.55 < z < 4.22$. All objects have FWHM < 2100 km/s and have high equivalent width lines for the CIV line (1549A) and Lyman-alpha line (1216A). We are currently using NIR spectroscopy (to look at the [OIII], H-alpha and H-beta lines) on the Apache Point Observatory 3.5m telescope in an attempt to examine several of our candidates for a broad component to the Balmer lines, the luminosity of [OIII], a proxy for the intrinsic bolometric luminosity of the objects, and the continuum slope at rest-frame 5000A to constrain the stellar population and stellar masses of host galaxies. Future plans include higher resolution NIR spectroscopy and spectroplarimetry (to look for evidence of a scattered broad-line region) of our candidates as well as comparison to existing data sets such as FIRST, WISE, and UKIDSS.

243.05 – **Analysis of Microvariability in ON 231**

James Raymond Webb[1], G. Bhatta[1], S. Dhalla[1], J. Pollock[2]

[1]*Florida International Univ.,* [2]*Appalachian State University.*

9:00 AM - 6:30 PM

We present a microvariability curve of ON 231 and analyze it in terms of a model based on synchrotron pulses. The model assumes that a shock propagates down the jet and enters a turbulent region where individual turbulent cells are responsible for individual synchrotron pulses that we observe as microvariabilty. This particular ON 231 light curve clearly shows individual pulses that can be de-convolved and fit with model pulses. We hope to be able to estimate individual turbulent cell characteristcs by this deconvolution and model fitting technique.

243.06 – **A Search of AGES for Active Black Holes in Merging Galaxies**

Kyle Schluns[1], J. Comerford[1], J. Greene[2], R. Cool[2]

[1]*University of Texas at Austin,* [2]*Princeton University.*

9:00 AM - 6:30 PM

An abundance of observations show that nearly all galaxies host a central supermassive black hole (SMBH). We also know that galaxy mergers are common within separations > 10 kpc. It is hard to estimate the galaxy merger rate directly, without knowing how many galaxy mergers exist within smaller separations. However, we can use pairs of active galaxies as an indirect tracer of it. We present two methods to search for active black holes in merging galaxies. Our first technique involves a search for double-peaked narrow line emissions that are a signature of a dual AGN merger. We identify two type 2 AGN with double-peaked Hb, [O III] 5007, Ha, and [N II] 6584 narrow emission lines selected from the AGN and Galaxy Evolution Survey (AGES). Through the use of double Gaussian fitting, we measure the red and blue components of offset velocity for each emission line. The double-peaked profiles may be explained by the orbital mechanics of dual AGN, bipolar outflows, or rotating gaseous disks. Additional observations are required to determine further clarification. Our second method includes a search for cases of dual SMBHs, where only one of the black holes is active. The AGN in one of the merging galaxies can be detected by a uniform offset in the emission line velocities. We detect five candidates of offset AGN, whose emission line offset velocities agree within each other's error. With the combination of our results and the other discoveries of kpc-scale galaxy mergers, we can produce a more detailed analysis of the rate and nuclear triggering of galaxy mergers.

243.07 – **Strong Iron Emission in Quasars: Testing a Thermal Model.**

Erin M. Cooper[1], K. Leighly[1]

[1]*University of Oklahoma.*

9:00 AM - 6:30 PM

FeII emission poses a long-standing yet important problem in studies of quasar broad emission lines. FeII emission is a primary coolant of the broad-line region, a primary player in the set of emission line correlations known as Eigenvector 1, and it can yield information about metallicity in the early Universe. It is generally thought that UV FeII emission has the same shape in all quasars, varying only in equivalent width; however, Leighly et al. 2007 identified two characteristic shapes. Typical quasars exhibit FeII emission in the ~2200-2600Å region. PHL 1811-like quasars exhibit additional FeII emission in the ~2200-2600Å region and excess emission in the regions ~2100-2200Å and ~1950-2050Å. Leighly et al. hypothesized the difference in shape arises from differences in Fe excitation and ionization in these strong Fe emitters: the emission in typical spectra arises from low-excitation FeII, and in PHL 1811-like spectra the emission arises from additional high-excitation FeII and FeIII.

We investigate the near-UV Fe emission in quasars by modeling strong iron emitters with templates generated using the atomic data in the Kurucz database. By grouping lines of similar upper energy level, we populate the levels according to the Boltzmann factor, as in a thermal gas. A preliminary fit of the strong iron emitter SDSS J124244.37+624659.1 shows the expected lower-excitation levels dominating the FeII emission. Analysis of the PHL 1811 spectrum shows the expected higher-excitation levels contributing to the FeII emission, and additional FeIII flux relative to the SDSS J124244.37+624659.1 spectrum. More analysis is needed to interpret the spectrum in the ~2000-2300Å range, where the excess of flux presents a challenge to model. Additional results will include a larger sample of strong Fe emitting quasars of both types.

This work is funded by NSF AST-0707703.

243.08 – **CHEERS! A Chandra and HST Survey Of Extended Emission-line Regions In Nearby Seyfert Galaxies**

Junfeng Wang[1], G. Fabbiano[1], M. Elvis[1], G. Risaliti[2]

[1]*Harvard-Smithonian CfA/SAO,* [2]*INAF-Arcetri Observatory, Italy.*

9:00 AM - 6:30 PM

Our CHEERS project is the `ultimate' resolution Chandra imaging survey of a far-IR selected sample of nearby active galactic nuclei. We will present our findings from detailed studies of NGC 4151, Mrk 573, and NGC 3393. With complementary high resolution HST and radio data, CHEERS resolves the detailed X-ray morphology of the extended narrow line region and obtain full picture of the multiphase ISM, allowing us to examine jet-ISM interactions and measure mass and momentum outflow rates to evaluate the importance of AGN feedback.

This work is supported by NASA grant GO1-12009X.

243.09 – **Active Galaxy Winds from X-ray, Ultraviolet, and Optical Studies of Nearby Seyfert 1s**

Lisa M. Winter[1]

[1]*CASA/University of Colorado-Boulder.*

9:00 AM - 6:30 PM

Mass outflows or winds from active galaxies may profoundly affect the evolution of their host galaxies by blowing away gas from star forming regions and recycling metals from near-nuclear supernovae into the galaxy disk. Such fundamental properties as the covering fraction, total energy, variability, and distance of these outflows are still unknown. We present new results in an effort to better understand the properties of active galaxy winds based on X-ray, optical, and UV observations of local Seyfert 1s. We show that the covering fraction, indicated through X-ray and optical spectroscopy, is higher than previous studies suggest. We also show new observations in the UV with the Hubble Space Telescope's Cosmic Origins Spectrograph (COS), showing that the UV variability is at a much lower level than X-ray variability. The COS observations also reveal weak Ly-alpha outflows, which were difficult/impossible to detect in previous generations of UV spectrographs.

243.10 – **Modeling the Power Spectra of Active Galaxies with Markov Chain Monte Carlo**

Kevin Marshall[1]

[1]*Widener Univ..*

9:00 AM - 6:30 PM

It is now well established that the power spectra of most active galaxies can be fit by a broken power law, with a break frequency that depends on both mass and accretion rate. Fitting the power spectrum and establishing appropriate error bars for the parameters is an intensive and time-consuming process, involving extensive Monte Carlo simulations to fit over a grid of paramters. Here we present a Markov Chain Monte Carlo (MCMC) method for fitting the power spectra, which allows for an appropriate estimation of both the best-fit values and their errors. Results are presented for the X-ray light curves of several objects, and comparisons are made to previous efforts in terms of accuracy.

243.11 – **Searching for AGN Signatures in HST WFC3/IR Grism Spectra of Clumpy Galaxies at 0.5 < z < 2**

Anna Han[1], K. Schawinski[1], B. D. Simmons[1], C. M. Urry[1], E. Glikman[1], S. Bamford[2], C. Lintott[3]

[1]*Yale University,* [2]*University of Nottingham, United Kingdom,* [3]*University of Oxford, United Kingdom.*

9:00 AM - 6:30 PM

The recent discovery of a “clumpy” galaxy with three actively growing black holes in separate clumps at z = 1.35 raises the possibility of supermassive black holes (SMBHs) forming in situ within gas clouds at later epochs than previously expected. We carry out a systematic search for 0.5 < z < 2 galaxies containing multiple active galactic nuclei (AGN) by examining clumpy galaxies with Hubble Space Telescope WFC3/IR grism survey data. We select our sample of clumpy galaxies using SExtractor and galaxy classifications from the Hubble Zoo citizen science project. We then analyze the grism data of individual clumps within each galaxy to characterize the probability of SMBHs forming and growing in the clumps of forming disk galaxies at 0.5 < z < 2.

243.12 – **Characterization of H-beta and [OIII] for Determining Black Hole Masses of Quasars**

Mallory Molina[1], M. J. Wolf[2], E. J. Hooper[2], A. I. Sheinis[2], P. H. Sell[2]

[1]*The Ohio State University,* [2]*University of Wisconsin-Madison.*

9:00 AM - 6:30 PM

We analyze the spectra of nearby, luminous quasars to calculate the black hole masses based on an empirical method by Vestergaard and Peterson (2006, ApJ, 641, 689), as well as to look at the forbidden [OIII] line for its credibility as a surrogate for estimating the stellar velocity dispersion of the host galaxy. Our initial measurements of the widths of the narrow [OIII] line in the quasar spectra preliminarily show no strong correlation to the measured stellar velocity dispersions of the host galaxies. For the black hole estimates we specifically concentrate on the H-beta spectral line. We use a multiple Gaussian fitting routine to isolate the broad lines from the narrow lines around H-beta. We measure the full width half maximum (FWHM) of the broad line and use that to solve for the black hole mass. While fitting the multiple Gaussians, we noted in some objects a shelf on the red side of H beta. This feature, which we suspect to be due to iron, complicates determination of the H-beta FWHM. To resolve this issue we are working with Brad Peterson from the Ohio State University to apply an iron template from Kovacevic, Popovic, and Dimitrijevic (2010, ApJS, 189, 15) that will be used to subtract this iron shelf from the H beta line. If we are able to sufficiently remove the shelf, we can then get a more accurate measure of the line width, and thus calculate more accurate black hole masses. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

243.13 – **Mid-infrared Selection Of AGN With WISE**

Daniel Stern[1], R. J. Assef[1], D. J. Benford[2], A. Blain[3], R. Cutri[4], P. R. Eisenhardt[1], R. L. Griffith[4], T. H. Jarrett[4], S. Lake[5], F. Masci[4], S. Petty[5], S. A. Stanford[6], C. Tsai[4], E. L. Wright[5], L. Yan[4], F. Harrison[7], K. Madsen[7]

[1]*JPL/ Caltech,* [2]*GSFC,* [3]*Leicester, United Kingdom,* [4]*IPAC/ Caltech,* [5]*UCLA,* [6]*UC-Davis/IGPP-LLNL,* [7]*Caltech.*

9:00 AM - 6:30 PM

The Wide-field Infrared Survey Explorer (WISE) is an extremely capable and efficient black hole finder. We present a simple mid-infrared color criterion, W1-W2 > 0.8, which identifies 60 AGN candidates per square-degree. This implies a much larger census of luminous AGN than found by typical wide-area optical surveys, attributable to the fact that mid-infrared selection identifies both unobscured (type 1) and obscured (type 2) AGN. Optical and soft X-ray surveys alone are highly biased towards only unobscured AGN, while this simple WISE selection likely identifies even heavily obscured, Compton-thick AGN. Using deep, public data in the COSMOS field, we explore the properties of WISE-selected AGN candidates. At the mid-infrared depths considered, 70 uJy at 3.4 microns and 160 uJy at 4.6 microns, this simple criterion identifies 78% of mid-infrared AGN candidates according to the criteria of Stern et al. (2005) with 95% reliability. We report on the demographics, multi-wavelength properties and redshift distribution of WISE-selected AGN candidates in the COSMOS field.

243.14 – **Monitoring Lower Luminosity AGN for Milli-Magnitude Variations**

Benjamin Boizelle[1], K. Bates[1], T. McCombs[1], J. Nelson[1], B. Little[1], J. Moody[1], J. Barnes[2]

[1]*Brigham Young University,* [2]*Salt Lake Community College.*

9:00 AM - 6:30 PM

A difficulty in providing a complete evolutionary history of AGNs with z is the faint absolute magnitudes of nearby AGN. These can be largely obscured by galaxy bulge light making their presence difficult to establish. The spectroscopic survey for lower luminosity AGNs (LLAGN) conducted by Ho, Filippenko and Sargent (1997), found that approximately a quarter of the bright, nearby galaxies (with dec > 0) contain LLAGNs. A few of these show characteristic quasar variability in time and magnitude, while others show low-level variability of indeterminate magnitude range. To better probe the luminosity range of nearby LLAGN variability, we are using the Remote Observatory for Variable Object Research (ROVOR) 16” telescope to monitor the 100 brightest, nearest LLAGN in filters that measure the continuum and H alpha emission separately. Our objects include Seyferts, LINERs, and sub-LINERs or transition objects. These are taken from the Ho et. al. survey (out to a redshift of z = 0.027), supplemented with slightly more distant and well-known objects (out to z = 0.05). We report on the survey and the first results in our endeavor to achieve milli-magnitude precision.

243.15 – **Continued Monitoring of Blazar-Like Optical Variability in Very Radio-Loud Narrow-Line Seyfert Galaxies**

Jeremy Maune[1], H. R. Miller[1], J. Eggen[1]

[1]*Georgia State University.*
9:00 AM - 6:30 PM

Observations within recent years appear to support the conclusion that there is a fundamental similarity between very radio-loud narrow-line Seyfert galaxies (RLNLSy1s) and the class of objects known as blazars. Being two classes of active galactic nuclei, it has long been well established that both types of objects are highly energetic, compact emission sources embedded in a host galaxy; ellipticals in the case of blazars, and spirals in that of Seyferts. Presumably, each is fueled through accretion onto a super-massive black hole, resulting in a relativistic jet released perpendicular to the plane of the disk. A blazar merely happens to be oriented so that this jet comes close to lying along the line of sight to the observer. We contend that this orientation is also true of the specific sub-type of Seyfert galaxies defined as RLNLSy1s, making them the spiral galaxy equivalent of a blazar.

The PEGA group at Georgia State University has instituted an observing program consisting of several RLNLSy1s in the hopes of detecting evidence of microvariability in these objects. As extremely rapid variability on time scales of days or even hours is one of the hallmarks of blazar activity, such detections would serve as a simple yet intriguing - though admittedly not definitive - support for the hypothesis. Our observations show that at least some RLNLSy1s do indeed demonstrate such mircovariability.

243.16 – **Ultraviolet Outflow Properties and Variability of Markarian 1513**

Barton Tofany[1], L. M. Winter[1], B. Borguet[2], C. Danforth[1], N. Arav[2], J. Green[1]

[1]*University of Colorado at Boulder,* [2]*Virginia Polytechnic Institute & State University.*
9:00 AM - 6:30 PM

We analyzed data from the Cosmic Origins Spectrograph (COS) to characterize the spectral properties and outflows of Markarian 1513. Further investigation using previous data collected by the Space Telescope Imaging Spectrograph (STIS), Goddard High Resolution Spectrograph (GHRS), and International Ultraviolet Explorer (IUE), was used to examine variability in the outflows along with the AGN emission and continuum luminosity spanning 32 years. The COS data contained one set of intrinsic absorption features, observed in: Lyman α, N V, Si IV, and C IV, which revealed an outflow velocity of −1525 km s−1. This kinematic feature prevailed through the historical Hubble Space Telescope observations spanning 15 years while exhibiting variability in both velocity and column densities. It was not, however, conclusively observed in the IUE data due to the lack of spectral resolution.

243.17 – **WFC3 Imaging Of z=6 Quasars: Examining The Host Galaxies Of AGN In The Early Universe**

Matt Mechtley[1], R. A. Windhorst[1], R. E. Ryan[2], S. H. Cohen[1], G. Schneider[3], X. Fan[3], N. P. Hathi[4], R. A. Jansen[1], W. C. Keel[5], A. M. Koekemoer[2], H. Röttgering[6], E. Scannapieco[1], D. P. Schneider[7], M. A. Strauss[8], H. Yan[9]

[1]*Arizona State University,* [2]*Space Telescope Science Institute,* [3]*University of Arizona,* [4]*Carnegie Institution of Washington,* [5]*University of Alabama,* [6]*Sterrewacht Leiden, Netherlands,* [7]*The Pennsylvania State University,* [8]*Princeton University,* [9]*University of Missouri - Columbia.*
9:00 AM - 6:30 PM

We present constraints on the properties of QSO host galaxies at z=6, using rest-frame ultraviolet imaging of the QSO J1148+5251. The data were collected by the Hubble Space Telescope Wide Field Camera 3 infrared channel in the F125W and F160W filters, and include contemporaneous observations of nearby stars to measure time-dependent components of the instrument point spread function (PSF). Using this observed PSF as a template, we construct model PSFs which are used to subtract the QSO point source from the images. We obtain a clean subtraction, but no detection of the host galaxy, to a 2σ limiting surface brightness of J > 24.45 AB mag arcsec^{-2} (H > 24.90 AB mag arcsec^{-2}). Assuming a Sérsic profile with r_e = 0.4" and n = 4, this corresponds to a host galaxy with an integrated total magnitude of J > 23.05 AB mag (H > 23.50 AB mag). Further, we test the reliability of this method to recover the host galaxy flux by simulating host galaxies with varying parameters and conducting the same analysis. We discuss cosmological implications of the associated luminosity, size, and mass limits.

Support for HST GO program #12332 is 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.

243.18 – **The New Generation Quasar SEDs from Radio to X-rays**

Zhaohui Shang[1], M. Brotherton[2], B. Wills[3], D. Wills[3]

[1]*Tianjin Normal University, China,* [2]*University of Wyoming,* [3]*University of Texas at Austin.*
9:00 AM - 6:30 PM

We have produced the next generation of quasar spectral energy distributions (SEDs), essentially updating the work of Elvis et al. by using high-quality data obtained with several space- and ground-based telescopes, including NASA's Great Observatories. We present an atlas of SEDs of 85 optically bright, non-blazar quasars over the electromagnetic spectrum from radio to X-rays. The heterogeneous sample includes 27 radio-quiet and 58 radio-loud quasars. Most objects have quasi-simultaneous ultraviolet-optical spectroscopic data, supplemented with some far-ultraviolet spectra, and more than half also have Spitzer mid-infrared Infrared Spectrograph spectra. The X-ray spectral parameters are collected from the literature where available. The radio, far-infrared, and near-infrared photometric data are also obtained from either the literature or new observations. We construct composite SEDs for radio-loud and radio-quiet objects and compare these to those of Elvis et al., finding that ours have similar overall shapes, but our improved spectral resolution reveals more detailed features, especially in the mid- and near-infrared.

243.19 – **Updating Standard Quasar Bolometric Luminosity Corrections**

Jessie C. Runnoe[1], M. Brotherton[1], Z. Shang[2]

[1]*University of Wyoming,* [2]*Tianjin Normal University, China.*
9:00 AM - 6:30 PM

Bolometric corrections are used in quasar studies to quantify total energy output based on a measurement of a monochromatic luminosity. We enumerate the practical difficulties of determining such corrections and present bolometric luminosities and corrections derived from the detailed spectral energy distributions of 63 bright quasars of low to moderate redshift. We explore several mathematical fittings to determine bolometric corrections and provide practical bolometric corrections of the traditional form as well as with an added constant at three wavelengths . The significant scatter in the 5100 angstrom bolometric correction can be reduced by adding a first order correction using the optical slope. We also provide X-ray bolometric corrections to the 2-10 keV luminosity. Finally, we recommend an adjustment to our bolometric corrections to account for viewing angle and the anisotropic emission expected from accretion discs.

243.20 – **The Discovery of 58 Extragalactic Water Masers by the Megamaser Cosmology Project**

James A. Braatz[1], J. Condon[1], V. Impellizzeri[2], A. Tilak[3], I. Zaw[4], Megamaser Cosmology Project Team

[1]*NRAO,* [2]*NRAO, Chile,* [3]*CfA,* [4]*NYU.*
9:00 AM - 6:30 PM

The Megamaser Cosmology Project (MCP) aims to determine the Hubble constant by measuring geometric distances to galaxies in the Hubble flow. Our measurements are based on observations of 22 GHz water vapor megamasers in the circumnuclear accretion disks of active galaxies. A second important goal of the project is to measure precise masses of the supermassive black holes in the galaxy nuclei. To reach these goals we must find new disk megamasers appropriate for distance and mass measurements. We use the Green Bank Telescope (GBT) to survey Seyfert 2 galaxies within $z \approx 0.04$, as well as smaller samples of luminous, nearby galaxies, and AGN detected by Swift. We have discovered 58 masers so far, about 40% of the total number of galaxies detected in the water maser line. Several of the newly detected masers are strong candidates for follow-up VLBI imaging to determine distances and black hole masses. Here we present results of our maser surveys, including GBT spectra of all the masers discovered by the MCP.

243.21 – **Simulations of Double-Bent Radio Sources**

Brian J. Morsony[1], J. J. Miller[2], S. Heinz[1], E. M. Wilcots[1], E. Freeland[3]

[1]*Univ. Of Wisconsin-Madison,* [2]*Univ. Of Colorado, Boulder,* [3]*Texas A&M University.*
9:00 AM - 6:30 PM

Observations of double-bent radio sources provide a powerful tool to probe the properties of the IGM in galaxy groups. We have carried out a series of simulations of AGN jets being bent by interaction with an external medium. This allows us to determine how different quantities affect the radius of curvature of the jets, and to quantify how accurately the density of the IGM can be determined from observations. We are also able to model the X-ray and extended radio emission that we predict to be associated with double-bent radio sources.

243.22 – **The Near-Infrared Variability of Quasars**

Adam Miller[1], J. S. Bloom[1], N. R. Butler[2]

[1]*UC Berkeley Astronomy Department,* [2]*Arizona State University.*
9:00 AM - 6:30 PM

We explore the intrinsic variability of quasi-stellar objects (QSOs) observed as part of the NEWFIRM Medium Band Survey (MBS). Using data obtained in 6 filters between 1 - 2.2 micron, we parameterize the structure function for variability in each of the filters

for the ~100 spectroscopically confirmed QSOs observed during the NEWFIRM MBS. Similar to recent optical studies we find that the structure function can be adequately modeled as a damped random walk. We characterize the differences in the variability in each of the six filters, and search for any trends between variability, redshift, and absolute magnitude. We compare this variability to that of known variable stars and examine the possibility of selecting QSOs from near-infrared (NIR) variability alone, regardless of color. Within the context of upcoming NIR synoptic surveys, e.g., WFIRST, EUCLID and SASIR, we suggest that QSOs can be discovered based on their intrinsic NIR variability.

243.23 – **Redshift Distribution in the Spitzer Mid-Infrared Quasar Survey**

Susan E. Ridgway[1], M. Lacy[2], A. Petric[3], T. Urrutia[4], A. Sajina[5]

[1]*NOAO,* [2]*NRAO,* [3]*Caltech,* [4]*AIP, Germany,* [5]*Tufts.*

9:00 AM - 6:30 PM

We have been undertaking a spectroscopic survey of luminous AGN and quasars selected in the mid-infrared from Spitzer shallow surveys. Mid-infrared selection is much less biased with respect to obscuration than optical techniques, and hence enables the discovery of obscured quasars as well as normal, unobscured ones. Our survey therefore provides an unique opportunity to construct luminosity functions for both obscured and unobscured quasars selected in the same way and covering similar redshifts and luminosities. Here we will present our current progress on the redshift distribution and luminosity function of this sample of type 1 & type 2 AGNs. In the 90% complete sample, we have over 400 confirmed AGN (including both Seyfert and quasar luminosities) from z = 0 to z=4.

243.24 – **Environmental And Clustering Properties Of Blazars From The Sloan Digital Sky Survey**

Kyle Willett[1], T. Nelson[1], L. Fortson[1]

[1]*University of Minnesota.*

9:00 AM - 6:30 PM

We present results from a large-scale study of the megaparsec-scale environments of blazars, including BL Lac objects and flat-spectrum radio quasars. Using the catalog of galaxies from the SDSS DR8, we compute spatial covariance amplitudes for a sample of more than 2900 blazars, the largest ever assembled. The covariance amplitudes are analyzed to compute the relative levels of clustering for various blazar types. We also compare the clustering of blazars to FRI and FRII radio galaxies to explore possibility of a parent population in the context of a blazar sequence. Finally, we present preliminary results on the morphologies of galaxies located within 1 Mpc of blazars, with classifications supplied by Galaxy Zoo data.

243.25 – **Investigating the Black Hole - Dark Matter Halo Connection in a New Sample of Local Active Galactic Nuclei**

Jordan Mirocha[1], J. Darling[1], M. Haynes[2], R. Giovanelli[2], ALFALFA Team

[1]*University of Colorado,* [2]*Cornell University.*

9:00 AM - 6:30 PM

Super-massive black holes (SMBHs) seem to be fixtures in the nuclei of nearly all galaxies, yet an understanding of the link between SMBHs and their hosts remains elusive. The correlation between SMBH mass and bulge stellar velocity dispersion first led to ideas of SMBH-galaxy coevolution, while recent work has highlighted the possibility that SMBHs coevolve with their hosts on scales well beyond the bulge. We investigate the relationship between SMBH mass and host dark matter halo mass in an HI-selected sample of Type 1 active galactic nuclei, for which virial SMBH mass estimation techniques apply. In agreement with previous studies, we find a correlation between SMBH mass and halo dynamical mass, albeit with significant scatter. Then, in conjunction with measurements drawn from the literature, we assess the dependence of the SMBH-halo mass relationship on galaxy properties such as HI mass, luminosity, and morphology. The results of residual and principal component analyses on this joint sample may hint at a new interpretation of observed SMBH-halo mass relations.

243.26 – **Magnetic Fields in Blazar Jets: Jet-Alignment of Radio and Optical Polarization over 20-30 Years**

Beverley J. Wills[1], M. F. Aller[2], C. Caldwell[1], H. D. Aller[2]

[1]*Univ. of Texas, Austin,* [2]*Univ. of Michigan, Ann Arbor.*

9:00 AM - 6:30 PM

Blazars are highly active nuclei of distant galaxies. They produce synchrotron-emitting relativistic jets on scales of less than a parsec to many Kpc. When viewed head-on, as opposed to in the plane of the sky, the jet motion appears superluminal, and the emission is Doppler boosted. Blazars show rapid radio and optical variability in flux density and polarization. There are two types of blazars that can have strong synchrotron continua: some quasars with strong broad emission lines, and BL Lac objects with weak or undetected broad lines. We have compiled optical linear polarization measurements of more than 100 blazars, including archival data from McDonald Observatory. While the optical data are somewhat sparsely sampled, The University of Michigan Radio Astronomical Observatory observed many blazars over 20-30 years, often well-sampled over days to weeks, enabling quasi-simultaneous comparison of optical and radio polarization position angles (EVPAs). We also collected data on jet direction -- position angles of the jet component nearest the radio core. The project is unique in examining the polarization and jet behavior over many years. BL Lac objects tend to have stable optically thin EVPA in the jet direction, meaning magnetic field is perpendicular to jet flow, often interpreted as the magnetic field compressed by shocks. In quasar-blazars optical and radio EVPA often changes between parallel or perpendicular to the jet direction, even in the same object. The underlying B field of the jet is is parallel to the flow, with approximately 90 degree changes resulting from shocks. For both BL Lac objects & quasars, the scatter in EVPA usually increases from low frequencies (4.8 GHz) through 14.5 GHz through optical. The wide optical-radio frequency range allows us to investigate optical depth effects and the spatial origin of radio and optical emission.

243.27 – **Star Formation in matched samples Of Active And Normal Galaxies**

Amanda Cordes[1], F. Hamann[1], V. Sarajedini[1], P. G. Pérez-González[2], G. Barro[2], M. Steinke[1]

[1]*University of Florida - Astronomy Department,* [2]*Universidad Complutense de Madrid (UCM), Spain.*

9:00 AM - 6:30 PM

Recent models of galaxy evolution predict that the fueling super-massive black holes in galactic nuclei, and thus the triggering AGN activity, should be accompanied by major episodes of star formation. However, the observational results have been mixed owing, perhaps, to the variety of circumstances being considered. We will present results from a study to compare star formation rates in a carefully matched sample of inactive and active galaxies within a small range of redshifts (roughly z ~ 0.2 - 0.3) and intermediate AGN and galaxy luminosities. Samples are selected in the Rainbow Extragalactic Database complied by e Pablo G. Pérez-González and Guillermo Barro, including specific data sets from Spitzer, IRAC and Subaru. Rainbow sources are matched to the Chandra Deep Field South point source catalog in order to locate AGN candidates. We eliminate sources inside the stern/lacey wedge where the AGN dominates the galaxy light. Star formation rates for both active and normal galaxies are acquired using multiband SED fitting.

243.28 – **No Quasar Left Behind**

Chelsea MacLeod[1], N. Butler[2], S. F. Anderson[1], R. Gibson[1], N. P. Ross[3], Z. Ivezic[1], A. Kimball[4], N. Brandt[5], M. Strauss[6], C. S. Kochanek[7], A. Myers[8]

[1]*University of Washington,* [2]*Arizona State University,* [3]*Lawrence Berkeley National Laboratory,* [4]*National Radio Astronomy Observatory,* [5]*Pennsylvania State University,* [6]*Princeton University,* [7]*The Ohio State University,* [8]*University of Wyoming.*

9:00 AM - 6:30 PM

Quasars are key astrophysical objects and cosmological probes. Using a selection method based on a "damped random walk" model, we obtained SDSS-III BOSS spectra of ~1500 unresolved sources in the SDSS Stripe 82, which exhibit photometric variability statistically similar to the variability of spectroscopically confirmed quasars. The targets were selected from 11,000 variable sources with 16.2 < i < 20.5. Our selection criteria were deliberately liberal, i.e., we aim for completeness rather than purity. The bright subset (i < 19) tests the completeness of the color-selected SDSS sample, while the faint subset represents a highly complete sample selected using a uniform photometric dataset and well-defined criteria. This new sample, as we show, verifies that quasars can be selected in a highly efficient manner (>95% purity) based on light curve information only, and that these light curves can be distinguished from those of variable stars with very little contamination.

243.29 – **Polarization Observations of Radio-Loud Narrow Line Seyfert 1**

Joseph R. Eggen[1]

[1]*Georgia State University.*

9:00 AM - 6:30 PM

Much work has been done recently on a small but interesting subclass of AGN, the radio loud NLS1s (R > 10). Several of these objects have been observed to posses properties similar to blazars, including blazar-like SEDs and the emission of gamma-rays, as detected by the FERMI/LAT instrument. As part of our ongoing monitoring program, we present here our observations for a sample of RL NLS1s. We have obtained polarimetric observations of several targets in order to determine if they exhibit significant or variable optical polarization, which is characteristic of blazars. Additionally, we utilize the public data available from the FERMI/LAT instrument to determine if any of these objects are radio-loud and variable. The results of these observations will be compared to those properties that are typical of blazars.

243.30 – **Adaptive Optics Imaging Of The Hidden Quasar IRAS 09104+4109**

Hien D. Tran[1]

[1]*W.M. Keck Observatory.*

9:00 AM - 6:30 PM

We present high-resolution J, H, K imaging of the ultra-luminous infrared galaxy and type 2 quasar IRAS 09104+4109 obtained with the laser guide star adaptive optics (LGS-AO) system at Keck Observatory. The observations were made with the NIRC2 narrow camera, using the AGN nucleus itself as the tip/tilt guide star, giving a resolution of ~0.07". In addition to extended emission-line filaments, we detect a small companion 0.68" to the north-east that could perhaps be a cluster member associated with the central active nucleus.

243.31 – **Using Radio Non-Detections to Determine the Relationship between Radio Loudness of AGN and their Fundamental Parameters**

Rachael Kratzer[1], G. T. Richards[1]

[1]*Drexel University.*
9:00 AM - 6:30 PM

While it is debated as to whether a dichotomy between radio-loud and radio-quiet quasars actually exists, the fact remains that some quasars are radio-loud while others are not. Using stacking analysis of radio-quiet optically-confirmed SDSS quasars (undetected by FIRST), we search for

trends in radio properties as a function of redshift and luminosity in

attempt to isolate the "parent sample" of radio-loud quasars. We further explore trends in radio properties as a function of two parameters of the CIV emission line (the equivalent width and the "blueshift"), which are correlated with the ionizing spectrum. The CIV emission line parameter space affords a unique way to probe the radio properties of undetected quasars: we predict that radio-quiet quasars at opposites extremes in their ionizing spectra will have very different median stacked radio properties. We further break our sample into smaller subsets (e.g., based on optical luminosity) to explore the radio-dependence on these parameters. Stacking subsets of quasars undetected by FIRST offers a fresh new insight to a frustratingly stagnant problem.

243.32 – **Multi-wavelength Analysis of Three Blazars**

Meridith Joyce[1], K. B. Marshall[2], M. R. Halford[3], H. Aller[4], M. Aller[4]

[1]*Bucknell University,* [2]*Widener University,* [3]*Cornell University,* [4]*University of Michigan.*
9:00 AM - 6:30 PM

Blazars are among the most powerful objects in the universe, demonstrating large-amplitude variability on short time scales and strong emission at all wavelengths. This project analyzes the behavior of three blazars: PKS 1510-089, 3C 454.3, and 3C 273. By constructing lightcurves for their radio, optical, X-ray, and gamma-ray bands and applying a discrete correlation function, or DCF, we were able to find correlations in the patterns of their emission, leading to physical insights which allowed us to consider possible models for these objects. Results include the detection of simultaneous flaring between the optical and gamma-ray bands of PKS 1510-089 as well as 3C 454.3.Other significant correlations were also found, lagged in some cases and simultaneous in others. The results of the correlation analysis support a physical model involving the synchrotron self-Compton (SSC) process for two of the three objects.

243.33 – **First Optical Spectra of Newly Detected Swift BAT AGN**

J. Drew Hogg[1], L. Winter[1], J. Tueller[2]

[1]*University of Colorado - Boulder,* [2]*NASA GSFC.*
9:00 AM - 6:30 PM

The Swift BAT hard X-ray survey is providing an unbiased look at AGN because in the 14-195 keV hard X-ray regime, dust and gas obscuration does not prevent their detection. We present the optical and X-ray spectra of 21 newly discovered BAT AGN from the 58 and 70-month catalogs and report their redshifts, optical properties, and classifications for the first time. The optical follow-ups were done with the 3.5-meter telescope at Apache Point Observatory in New Mexico over 6 half-nights. The newly detected sources are either fainter, or more distant than the sources in the previous catalogs. The sample has a redshift range of z = 0.02 to 0.16, with the more obscured AGN at the lower redshifts. Ten of the sources exhibit broadlines (47%), indicative of Seyfert 1s, nine exhibit narrowlines (43%), indicative of Seyfert 2s, and two (10%) do not show any lines and have a flat spectrum.

243.34 – **Fueling AGN: A Comparison of Nuclear Gas Characteristics in Seyfert & Quiescent Galaxies**

Austin Rivers[1], E. K. S. Hicks[1], R. I. Davies[2], M. A. Malkan[3]

[1]*University of Washington,* [2]*MPE, Germany,* [3]*UCLA.*
9:00 AM - 6:30 PM

Although it is widely accepted that supermassive black holes rest at the centers of most, if not all, galaxies in our universe, it is not understood what is responsible for driving material down to the black holes in Seyfert galaxies generating active galactic nuclei (AGN) while other galaxies lack this central activity and remain quiescent. Using high resolution, 2D integral field data from the Keck and VLT telescopes we can now observe the central few hundred parsecs in local galaxies to determine what is unique about Seyfert galaxies that leads to the fueling of AGN. With a sample of Seyfert and quiescent galaxies matched based on host galaxy properties, we identify differences in the observed characteristics of the nuclear molecular gas. First results show that the Seyfert galaxies have a greater central accumulation of molecular gas, with as much as five times more mass within the central 50pc compared to quiescent galaxies. The distribution of the gas is suggested to be, regardless of AGN classification, disk-like based on the best fit Sersic indices. A comparison of the azimuthally averaged velocity and velocity dispersion in this matched sample will also reveal differences in nuclear properties such as the height of the molecular gas disk and the column density of the nuclear gas.

243.35 – **Identifying Seyfert AGN Fueling Mechanisms on Scales from 1 kpc to 10 pc**

Erin K. Hicks[1], R. I. Davies[2], M. A. Malkan[3], A. Rivers[1]

[1]*University of Washington,* [2]*MPE, Germany,* [3]*University of California, Los Angeles.*
9:00 AM - 6:30 PM

With adaptive-optics assisted integral field spectroscopy we are now able to probe spatial scales that are directly relevant to fueling of Seyfert active galactic nuclei (AGN). While on larger scales Seyfert galaxies appear identical to quiescent galaxies, they are undergoing unknown processes on scales of tens of parsecs that result in feeding of their central black holes and the generation of AGN. Though a comparison of a sample of Seyfert and quiescent galaxies matched in host galaxy characteristics, we identify several key properties that are unique to Seyfert galaxies, and thus their nuclear activity, and we use these to constrain the dynamical processes that dictate black hole accretion rates in Seyferts. Simultaneously measuring the stellar and molecular gas kinematics on scales from 1 kpc down to 10 pc we compare nuclear properties such as the gas content within the central 100 pc, the prevalence of thick nuclear gas disks, the significance of non-circular motions, the frequency of central stellar dispersion drops indicative of past inflow of the interstellar medium, and the characteristics of the nuclear star formation (rates and age of last episode). In several cases we see evidence of inflow along nuclear spiral and bar structures. Results will also be presented from an ongoing effort to interpret the observed molecular gas non-circular kinematic signatures, and estimate inflow rates, via comparison with theoretical dynamical models. Through such modeling we will identify the primary mechanisms responsible for Seyfert AGN fueling and assess the potential impact of these processes on galaxy evolution.

243.37 – **Observations of 4 Blazars with the Robotically Controlled Telescope in 2011**

Michael T. Carini[1], R. Brown[1]

[1]*Western Kentucky Univ..*
9:00 AM - 6:30 PM

During 2011, four Blazars were intensively monitored in the R band with the Robotically Controlled Telescope (RCT): 3C 273, 3C 279, BL Lacertae and 1ES 1028+511. We present the results of this optical R band monitoring and demonstrate the vast potential of the RCT as an instrument for monitoring Blazars and other astronomical phenomena with time variable continuum emission.

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244 – Dwarf and Irregular Galaxies

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

244.01 – **ATCA/CABB Radio Continuum Imaging of Nearby Star-Forming Dwarf Galaxies**

Qingyang Liu[1], J. M. Cannon[1]

[1]*Macalester College.*
9:00 AM - 6:30 PM

We present new multi-configuration ATCA/CABB 3 and 6 cm radio continuum images of the nearby star-forming dwarf galaxies NGC 55 and IC 5152. The wide bandwidth (2 GHz per frequency) allows an unprecedented decomposition of thermal and non-thermal emission components on a spatially resolved basis within each galaxy. To achieve this, we image eight 256 MHz-wide segments within each frequency band, producing 16 measurements of the radio spectral energy distribution in each galaxy. Regions dominated by thermal emission are easily identified by their characteristic flat spectral indices. Regions with a mixture of thermal and non-thermal components can be identified by a comparison with H Alpha imaging. Future observations at higher frequencies will identify the break in the spectral energy distribution in such sources and eliminate the dependence on optical imaging to differentiate thermal and non-thermal radio components in nearby galaxies.

244.02 – **EVLA Radio Continuum Imaging of Nearby Dwarf Galaxies**

Elijah Bernstein-Cooper[1], J. M. Cannon[1], L. Chomiuk[2], A. Kepley[3], E. Wilcots[4]
[1]Macalester College, [2]Harvard, NRAO, [3]University of Virginia, [4]University of Wisconsin - Madison.
9:00 AM - 6:30 PM

We present preliminary EVLA/WIDAR snapshot L-band radio continuum imaging of four nearby dwarf galaxies: NGC 2366, NGC 783, WLM, and Pegasus. We exploit the 1 GHz bandwidth of these observations to create images of the sources in multiple ~120 Mhz wide spectral windows. The radio continua of NGC 2366 and NGC 784 are compared with multiwavelength images (including GALEX near UV, continuum subtracted H alpha, and Spitzer FIR) to probe the nature of thermal and nonthermal emission on a spatially resolved basis. These data are the first results from a larger and more comprehensive study of the radio continua of nearby star-forming dwarf galaxies with the EVLA.

244.03 – **Dynamical Modeling Of SHIELD Galaxies: AGC 749237**

Clara Thomann[1], J. M. Cannon[1], E. C. Elson[2], R. Giovanelli[3], M. P. Haynes[3], E. A. K. Adams[3], K. B. W. McQuinn[4], J. Ott[5], A. Saintonge[6], J. J. Salzer[7], E. D. Skillman[4]
[1]Macalester College, [2]International Centre for Radio Astronomy Research, The University of Western Australia, Australia, [3]Cornell University, [4]University of Minnesota, [5]National Radio Astronomy Observatory, [6]Max Planck Institut fuer Astrophysik, Germany, [7]Indiana University.
9:00 AM - 6:30 PM

The “Survey of HI in Extremely Low-mass Dwarfs” is a systematic exploration of the neutral gas contents and dynamics of 12 ALFALFA-selected galaxies with HI masses between 10^6 and 10^7 solar masses. AGC 749237 is amenable to in-depth dynamical analysis using high spectral resolution (0.83 km s^{-1} ch^{-1}) EVLA B and C configuration observations. Tilted ring analysis in GIPSY is performed at three spatial resolutions (~81.5 pc, 163 pc, and 326 pc). While the small-scale kinematics indicate some non-circular motions, the extracted rotation curve flattens at 28±3 km s^{-1} at radii between 81.5 and 620.5 pc. From this we infer a total dynamical mass of $(1.1\pm0.2)\times10^8$ solar masses.

244.04 – **The Survey Of HI In Extremely Low-mass Dwarfs (shield)**

John M. Cannon[1], C. M. Thomann[1], R. Giovanelli[2], M. P. Haynes[2], S. Janowiecki[3], A. Parker[3], J. J. Salzer[3], E. A. K. Adams[2], E. C. Elson[4], E. Engstrom[1], S. Huang[2], K. B. W. McQuinn[5], J. Ott[6], A. Saintonge[7], E. D. Skillman[5], J. Allan[1], G. Erny[1], P. Fliss[1], A. Smith[1]
[1]Macalester College, [2]Cornell University, [3]Indiana University, [4]International Centre for Radio Astronomy Research, The University of Western Australia, Australia, [5]University of Minnesota, [6]National Radio Astronomy Observatory, [7]Max Planck Institut für Astrophysik, Germany.
9:00 AM - 6:30 PM

We present first results from the Survey of H I in Extremely Low-mass Dwarfs (SHIELD), a multi-configuration Expanded Very Large Array (EVLA) study of the neutral gas contents and dynamics of galaxies with H I masses in the 10^6-10^7 Solar mass range detected by the Arecibo Legacy Fast ALFA (ALFALFA) survey. We describe the survey motivation and concept demonstration using Very Large Array imaging of six low-mass galaxies detected in early ALFALFA data products. We then describe the primary scientific goals of SHIELD and present EVLA and WIYN 3.5m imaging of the 12 SHIELD galaxies. Optical and infrared imaging of the sample is currently being obtained with the Hubble Space Telescope and the Spitzer Space Telescope. When complete, SHIELD will provide a unique opportunity to study the structural parameters and star formation properties of the galaxies that inhabit the faint end of the HI luminosity function.

244.05 – **Neutral Hydrogen Observations of the Lyman Alpha Reference Sample**

Stephen Pardy[1], J. M. Cannon[1], G. Ostlin[2], F. Duval[2], M. Hayes[3], D. Kunth[4], M. Mas-Hesse[5], D. Schaerer[6]
[1]Macalester College, [2]Stockholm Observatory, Sweden, [3]Observatoire Midi-Pyrenees, France, [4]Institut d'Astrophysique de Paris, France, [5]Laboratorio de Astrofisica Espacial y Fisica Fundamental, Spain, [6]Observatoire de Geneve.
9:00 AM - 6:30 PM

We present new HI spectra of 14 systems in the Lyman Alpha Reference Survey (LARS) obtained with the 100m Green Bank Telescope (GBT). LARS is a detailed study of the processes governing the production, propagation, and escape of Lyman Alpha photons in 14 UV-selected star-forming galaxies. The new GBT spectra robustly detect the HI spectral line in 7 of the 14 observed LARS galaxies; the remaining 7 are either confused or non-detections at our current sensitivity limits (~6.6×10^9 Solar masses at a characteristic distance of 237 Mpc). The GBT profiles, combined with SDSS imaging, are used to examine various global properties of the detected LARS galaxies.

244.06 – **On the Origin of the Supergiant HI Shell and Putative Companion in NGC 6822**

Erin O'Leary[1], J. M. Cannon[1], D. R. Weisz[2], E. D. Skillman[3], A. E. Dolphin[4], F. Bigiel[5], A. A. Cole[6], W. J. G. de Blok[7], F. Walter[8]
[1]Macalester College, [2]University of Washington, [3]University of Minnesota, [4]Raytheon Company, [5]University of Heidelberg, Germany, [6]University of Tasmania, Australia, [7]University of Cape Town, South Africa, [8]Max-Planck-Institute for Astronomy, Germany.
9:00 AM - 6:30 PM

We present new Hubble Space Telescope Advanced Camera for Surveys imaging of six positions spanning 5.8 kpc of the HI major axis of the Local Group dIrr NGC 6822, including both the putative companion galaxy and the large HI hole. The resulting deep color magnitude diagrams show that NGC 6822 has formed >50% of its stars in the last ~5 Gyr. The star formation histories of all six positions are similar over the most recent 500 Myr, including low-level star formation throughout this interval and a weak increase in star formation rate during the most recent 100 Myr. Stellar feedback can create the giant HI hole, assuming that the lifetime of the structure is longer than 500 Myr; such long-lived structures have now been observed in multiple systems and may be the norm in galaxies with solid-body rotation. The old stellar populations (red giants and red clump stars) of the putative companion are consistent with those of the extended halo of NGC 6822; this argues against the interpretation of this structure as a bona fide interacting companion galaxy and against its being linked to the formation of the HI hole via an interaction.

244.07 – **Exploring Optically Compact Dwarf Galaxies for Kinematic Structures and Extended HI Halos**

Hans Most[1], J. M. Cannon[1], J. J. Salzer[2], J. L. Rosenberg[3]
[1]Macalester College, [2]Indiana University, [3]George Mason University.
9:00 AM - 6:30 PM

We present Very Large Array H I spectral line and optical imaging of eight optically compact (optical radii <1 kpc), star-forming dwarf galaxies. These galaxies were chosen because of their optically compact stellar distributions, faint blue magnitudes, ongoing star formation, and relative proximity. The sample includes ADBS 113845+2008, which was found to have an HI halo that extends nearly 40 optical scale lengths from the stellar body (Cannon et al. 2009). Using this larger sample, we are working to discern if the "giant gas disk" dwarf galaxy is common or rare. We are also exploring the kinematics and dark matter contents of each of the sample galaxies.

244.09 – **Local Tadpole Galaxies**

Debra M. Elmegreen[1], B. G. Elmegreen[2], J. Sanchez Almeida[3], C. Munoz-Tunon[3], J. Putko[4], J. Dewberry[1]
[1]Vassar College, [2]IBM T.J. Watson Research Center, [3]Instituto de Astrofisica de Canarias, Spain, [4]Middlebury College.
9:00 AM - 6:30 PM

Tadpole galaxies have a giant star-forming region at the end of an elongated intensity distribution. The origin of this asymmetric structure is not known, although suggestions range from ram pressure to mergers. We use SDSS data to determine the ages, masses, surface densities, and star formation rates of the heads and tails in 13 local tadpoles identified from Kiso and Michigan surveys and compare them to tadpoles previously surveyed in the Hubble Ultra Deep Field. The young stellar mass in the head scales linearly with restframe galaxy luminosity, ranging from 10^5 M_o at galaxy U = -13 mag to 10^9 M_o at U = -20 mag. The young star surface density in the head is relatively small for local tadpoles, ~ 1 M_o pc^{-2}, but much larger for high redshift tadpoles, 10 - 100 M_o pc^{-2}. The star formation rate per unit area increases with increasing redshift by 2 orders of magnitude from z=0 to 3.

J. Putko was supported through NSF REU grant AST-1005024, and J. Dewberry through the Vassar URSI program.

244.10 – **NGC4449B: A New Extreme Tidally Disrupting Dwarf Galaxy Near NGC4449**

Christine Black[1], R. M. Rich[1], F. Longstaff[1], D. B. Reitzel[1]
[1]University of California, Los Angeles.
9:00 AM - 6:30 PM

NGC4449 is a Magellanic irregular galaxy with M_B~-18, roughly twice the luminosity of the LMC and located 3.82 Mpc from the Milky Way. We report the discovery of a new very low surface brightness dwarf companion at a projected distance if 9 kpc from the galaxy. It has a full extent of 3.5 X 7.5 kpc, with the morphology of a compact core and

extended tidal tails that are roughly aligned in the direction of NGC 4449. Preliminary estimates find M_r = -13, making this a relatively luminous, yet very large, dwarf galaxy. The structure of NGC4449B is consistent with a dwarf galaxy on its first encounter, undergoing tidal disruption. Despite large amounts of HI in the vicinity, we see no signs of star formation in the dwarf and speculate that its stellar population is old. The extreme tidal structure and low surface brightness, as well as close projected distance, secure the association with NGC 4449.

244.11 – **EVLA Observations of the Leo Ring**

Brian R. Kent[1], A. Chung[2], J. M. Wrobel[1], J. Ott[1], G. E. Morrison[3], K. Bekki[4], H. Park[2]

[1]*NRAO,* [2]*Yonsei University, Korea, Republic of,* [3]*IfA-UHawaii/CFHT,* [4]*University of New South Wales, Australia.*

9:00 AM - 6:30 PM

We present new EVLA D-configuration data of the Leo Ring. The 21cm observations show high spatial and spectral resolution maps of the ring in neutral hydrogen.

The region associated with the ring is located at a distance of 10 Mpc,

and consists of an intermediate density group of galaxies when compared with the denser Virgo Cluster to the east. Whereas single-dish observations are sensitive to large-scale diffuse features,

the interferometric data are sensitive to the population of small dwarf galaxies (~ 0.08 Jy km/s and 20 km/s).

The nine field mosaic (covering the 200 kpc diameter HI ring) consists of 8 hours per field with a 4 MHz bandwidth (covering over 800 km/s in *cz* space) on the new EVLA WIDAR correlator allowing for coverage of all the spectral features of the ring and galaxy group. The correlator setup gives a 1.953 kHz channel spacing (~ 0.5 km/s at the HI line). The synthesized beam for this configuration is ~ 45" (2.2 kpc at the Leo distance).

The data allow us to constrain models for the origin of the HI ring (primordial vs. stripped)

and to search for dwarfs in the ring to a limiting HI mass of ~ 10^6 $M_\odot$.

We report on preliminary HI results and compare with the CFHT mosaic images from the literature.

244.12 – **Regulating Star Formation in High-Redshift Dwarf Galaxies through Radiation Pressure**

John Wise[1]

[1]*Georgia Institute of Technology.*

9:00 AM - 6:30 PM

We present a suite of adaptive mesh refinement radiation hydrodynamics simulations that follows the transition from Population III to II star formation. We model stellar radiative feedback with adaptive ray tracing, including the momentum coupling to the gas. A top-heavy initial mass function for the Population III stars is considered, resulting in a plausible distribution of pair-instability supernovae and associated metal enrichment. We find that the gas fraction recovers from 5 percent to nearly the cosmic fraction in halos with merger histories rich in halos above 10^7 \Ms. A single pair-instability supernova is sufficient to enrich the host halo to a metallicity floor of 10^{-3} $Z_\odot$ and to transition to Population II star formation. This provides a natural explanation for the observed floor on damped Lyman alpha (DLA) systems metallicities reported in the literature, which is of this order. We find that stellar metallicities do not necessarily trace stellar ages, as mergers of halos with established stellar populations can create superpositions of *t-Z* evolutionary tracks. A bimodal metallicity distribution is created after a starburst occurs when the halo can cool efficiently through atomic line cooling. We find that radiation pressure plays a key role in self-regulating star formation and preventing the overproduction of stars in early dwarf galaxies.

244.13 – **BCD Galaxies from In-spiraling Giant Clumps**

Bruce Elmegreen[1], H. Zhang[2], D. A. Hunter[3]

[1]*IBM Research Div.,* [2]*Lowell Observatory and Purple Mountain Observatory,* [3]*Lowell Observatory.*

9:00 AM - 6:30 PM

Giant star-formation clumps in dwarf irregular galaxies can have masses exceeding a few percent of the galaxy mass enclosed inside their orbital radii. They can produce sufficient torques on dark matter halo particles, halo stars, and the surrounding disk to lose their angular momentum and spiral into the center in less than 1 Gyr. Pairs of giant clumps with similarly large relative masses can interact and exchange angular momentum to the same degree. The result of this angular momentum loss is a growing central concentration analogous to a bulge in an earlier-type galaxy. A long history of inward migration will also produce a long-lived starburst in the inner regions as the gas column density remains above a threshold for star formation. Such a burst may be identified with the BCD phase in some dwarfs. Observations of giant star formation clumps in five local dwarf irregulars illustrate the relatively large clump masses that are suggested by this process. The observed clumps also seem to contain old field stars, even after background light subtraction, in which case they may be gravitationally bound and long-lived. The two examples with clumps closest to the center have the largest relative clump masses and the greatest contributions from old stars. This work was funded in part by the National Science Foundation through grants AST-0707563 and AST-0707426 to DAH and BGE. HZ was partly supported by NSF of China through grants #10425313, #10833006 and #10621303 to Professor Yu Gao.

244.14 – **The Attraction of Dwarfs**

Marshall L. McCall[1]

[1]*York University, Canada.*

9:00 AM - 6:30 PM

Recent near-infrared observations of star-forming dwarf galaxies whose gas motions are predominantly disordered are employed to confront theoretical predictions for the relationship between baryonic mass and kinematics. The baryonic Tully-Fisher relation for the dwarfs has a slope which is half that predicted by Modified Newtonian Dynamics (MOND), but which agrees exactly with that predicted by Modified Gravity (MOG). MOG also correctly predicts an upturn in slope for heavier galaxies around the mass where it is observed, but the rate of change of slope is not rapid enough to yield as good a fit to rotators as MOND. Standard cosmology fails to fit any of the data.

244.15 – **Direct Oxygen Abundances for the Lowest Luminosity LVL Galaxies**

Danielle Berg[1], E. D. Skillman[1], A. R. Marble[2], L. van Zee[3], C. W. Engelbracht[4]

[1]*University of Minnesota,* [2]*National Solar Observatory,* [3]*Indiana University,* [4]*University of Arizona.*

9:00 AM - 6:30 PM

We present new MMT spectroscopic observations of HII regions in 42 of the lowest luminosity galaxies in the Spitzer Local Volume Legacy (LVL) survey. For 31 of the galaxies in our sample we were able to measure the [OIII] λ4363 auroral line at a strength of 4σ or greater, and thus determine oxygen abundances using the direct method. Direct oxygen abundances were compared to B-band luminosity, 4.5 μm luminosity, and stellar mass to characterize the luminosity-metallicity (L-Z) and mass-metallicity (M-Z) relationships at low-luminosity.

We examined a "Combined Select" sample composed of 38 objects, from the present sample and the literature, with direct oxygen abundances and reliable distance determinations (based on the tip of the red giant branch or Cepheid variables). The B-band and 4.5 μm L-Z relationships were found to be $12+\log(O/H) = (6.19\pm0.07) + (-0.12\pm0.01)M_B$ and $12+\log(O/H) = (5.93\pm0.11) + (-0.11\pm0.01)M_{[4.5]}$ with dispersions of σ = 0.17 and σ = 0.14 respectively. Since the slope of the L-Z relationship doesn't seem to vary from the optical to the near-IR, as has been observed in studies of more luminous galaxies, we propose that less extinction due to dust is created in the lowest luminosity galaxies. We subsequently derived a M-Z relationship of $12+\log(O/H) = (5.49\pm0.23) + (0.31\pm0.03)\log M*$, with a dispersion of σ = 0.16. None of the relationships seem to hold an advantage with respect to dispersion, supporting the idea of minimized dust.

Additionally, the trend of N/O abundance with respect to B-V color and oxygen abundance was examined. Similar to the conclusions of van Zee & Haynes (2006), we find a positive correlation between N/O ratio and B-V color: $\log(N/O) = 0.92$ (B-V) - 1.83. Furthermore, there are no objects with high N/O ratio below $12+\log(O/H)=7.9$.

244.16 – **A Complete Census of Dusty Evolved Stars in Local Group Dwarf Galaxies with Spitzer: Description and First Results**

Martha L. Boyer[1], P. Barmby[2], A. Z. Bonanos[3], R. D. Gehrz[4], K. D. Gordon[1], M. A. T. Groenewegen[5], E. Lagadec[6], D. J. Lennon[1], M. Marengo[7], K. McQuinn[4], M. Meixner[1], E. D. Skillman[4], G. C. Sloan[8], J. T. van Loon[9], A. A. Zijlstra[10]

[1]*STScI,* [2]*University of Western Ontario, Canada,* [3]*National Observatory of Athens, Greece, Greece,* [4]*University of Minnesota,* [5]*Royal Observatory of Belgium, Belgium,* [6]*ESO, Garching, Germany,* [7]*Iowa State University,* [8]*Cornell University,* [9]*Keele University, United Kingdom,* [10]*University of Manchester, United Kingdom.*

9:00 AM - 6:30 PM

Highly evolved stars (massive stars and intermediate−mass Asymptotic Giant Branch −or AGB− stars) can become heavily enshrouded in dust. This material is ejected into the interstellar medium (ISM), driving galactic chemical evolution. The dwarf galaxies of the Local Group (LG) are ideal laboratories for studying dusty evolved stars since their stellar populations are resolvable and they span a wide range in metallicity, luminosity, star formation history, ISM content, and interaction history. The dust−producing phase is brief, so it is rare in low−luminosity dwarf galaxies. We must therefore observe a large sample of dwarf galaxies in order to build a sufficient evolved star database. We have obtained time with the Spitzer Space Telescope to complete a uniform census of LG dwarf galaxies (d < 2 Mpc) with IRAC designed to detect and characterize the circumstellar dust around evolved stars. The scientific potential of such observations is immense, since IRAC provides the color information required for identifying dusty stars

that are obscured in optical and near-infrared surveys. Our immediate science goals are to (1) analyze dust content and mass loss in AGB stars, (2) generate intermediate−age star formation histories using AGB stars, (3) analyze the infrared properties of massive evolved stars, and (4) identify targets for JWST follow−up. Here, we describe the program and present some first results.

244.17 – **The Splash Survey: Washington+ddo51 Photometry Of M31 Dsphs**

Rachael Beaton[1], E. Tollerud[1], S. R. Majewski[1], R. J. Patterson[1], SPLASH Collaboration

[1]*Univ. of Virginia.*

9:00 AM - 6:30 PM

We present Washington+DDO51 photometry for 15 dwarf Spheroidal galaxies (dSphs) in the Andromeda stellar halo as part of the Spectroscopic and Photometric Landscape of the Andromeda Stellar Halo (SPLASH) survey. The Washington+DDO51 filter system is uniquely able to identify the small fraction of M31 red giant branch (RGB) stars among the overwhelming sky density of foreground Milky Way dwarf stars at similar surface temperatures. Thus, this approach provides an unparalleled opportunity to probe these already diffuse satellites to their even lower densities at larger angular radii and trace the structure the structure of each dSph to at least five times the sensitivity of previous photometric surveys. Apart from using the identified RGB candidates to derive structural parameters of each satellite, we also use isochrone fitting techniques to derive estimates of the satellite tip of the RGB distances and metallicities.

244.18 – **Detailed Chemical Abundances of Andromeda Satellites from Co-added Spectra**

Lucy Cheng[1], P. Guhathakurta[2], E. Kirby[3], L. Yang[4], SPLASH collaboration

[1]*The Harker School,* [2]*UC Santa Cruz,* [3]*Caltech,* [4]*KIAA/Beijing U, China.*

9:00 AM - 6:30 PM

In the past, detailed chemical abundance measurements were limited to stars in the Milky Way and its dwarf satellites since stars in more distant galaxies are too faint for even the most powerful telescopes to obtain the high signal-to-noise spectra needed for such measurements. In this project, we co-added low signal-to-noise spectra of individual red giant stars with similar photometric properties to create high signal-to-noise spectra free of instrumental artifacts. We compared the resulting spectra to a collection of "model" spectra, which are generated from realistic computer models of the interiors of stars. These spectra mimic the behavior of stellar spectra over a wide range of properties, most notably the iron to hydrogen ratio. By adopting the abundance measurements of the best-fit model spectra, we measured iron and alpha element abundances for Andromeda dwarf satellites NGC 147, NGC 185, And I and And II, thereby expanding the data set of detailed abundance measurements beyond the Milky Way for the first time. We found that the abundance of alpha elements decreases as the abundance of iron increases, and that the abundance of iron increases with increasing satellite luminosity, similar to the trends seen in Milky Way dwarf spheroidal satellites. The similarity between Andromeda dwarf spheroidals (And I and And II) and dwarf ellipticals (NGC 147 and NGC 185) in these relations shows that these two galaxy types are closely related. We also calibrated the photometric iron abundance estimates with spectroscopic ones, resulting in more accurate photometric estimates that can be used in future projects.

This research was supported by the Science Internship Program (SIP) at UCSC and the National Science Foundation.

244.19 – **Probing The Structure And Kinematics Of The Transition Layer Between The Magellanic Stream And The Halo In HI**

Lou Nigra[1], S. Stanimirovic[1], J. S. Gallagher, III[1], K. Wood[2], F. J. Lockman[3], D. Nidever[4], S. Majewski[4]

[1]*University of Wisconsin,* [2]*University of St. Andrews, United Kingdom,* [3]*National Radio Astronomy Observatory,* [4]*University of Virginia.*

9:00 AM - 6:30 PM

The Magellanic Stream (MS) is a prominent local example of a gaseous galactic halo remnant. Spanning the Southern Galactic sky behind the Magellanic Clouds, it presents a nearby laboratory with which to study the fate of cool gas streams injected into a galactic environment, considered possible fuel sources for sustained star formation. We present results based on 21 cm observations on the MS from the Green Bank Telescope (GBT) that, through special data reduction, averaging and 3D modeling techniques, reach more than five times the sensitivity of existing maps while essentially retaining the 9' base GBT resolution. This provides a crude, but unprecedented peek into the 3D structure and kinematics of the diffuse neutral component that traces the warm, highly ionized MS-to-Halo transition layer. Previously, this has been probed only through a small number of optical and UV metal absorption sight lines. Understanding the ablation process mediated by this layer as the gas works its way through the halo at high shear velocities is crucial in evaluating the potential for intruding gas to reach a galaxy disk. Under these conditions, hydrodynamic instabilities such as Rayleigh-Taylor can operate on small scales, creating a complex thermal and kinematic environment, strongly influencing the overall mass transfer rate and, therefore the lifetime of the injected cool gas. A turbulent mixing layer is generally pictured as a strong candidate for this interface and we show how the results fit into that picture.

244.20 – **Orbit-based Dynamical Models of the Draco Dwarf Spheroidal**

John Jardel[1], K. Gebhardt[1], M. Fabricius[2], N. Drory[3]

[1]*The University of Texas,* [2]*Max Planck Institute for Extraterrestrial Physics (MPE), Germany,* [3]*Universidad Nacional Autónoma de México, Mexico.*

9:00 AM - 6:30 PM

TITLE: Orbit-based Dynamical Models of the Draco Dwarf Spheroidal

ABSTRACT:

We construct axisymmetric Schwarzschild models of the Draco dwarf spheroidal galaxy in an effort to determine the inner slope of the dark matter density profile. These models are also capable of determining the orbital aniostropy of the stars by fitting to kinematics in the form of line-of-sight velocity distributions (LOSVDs). We use individual radial velocities of stars to construct the LOSVDs, drawing on data from the literature as well as data taken with the VIRUS-W integral field spectrograph on the 2.7m telescope at McDonald Observatory. The advantage of this instrument is that its fibers are closely separated; this allows for simultaneous observations of many stars in the center of the galaxy. Using this technique, we observed 12 member stars within the central 20 pc of Draco. The LOSVD of these 12 stars is used to constrain the mass in the central region of the galaxy, and allows us to determine the inner dark matter density profile as well as investigate the possibility of a central black hole.

244.21 – **Metallicity Distribution Function for Leo I Based on HST WFC3 Photometry**

Teresa Ross[1], J. Holtzman[1], B. J. Anthony-Twarog[2], A. Saha[3]

[1]*New Mexico State University,* [2]*University of Kansas,* [3]*NOAO.*

9:00 AM - 6:30 PM

We present a preliminary metallicity distribution function (MDF) for Leo I, derived from photometry with the Wide Field Camera 3 (WFC3) aboard the Hubble Space Telescope (HST). We obtained relatively high S/N photometry in V (F555W), I (F814W) and Ca H & K (F390M) for giants. Using the medium band filter that covers the Ca H & K lines - the strongest metal absorption lines in the visible spectrum - in conjunction with the V and I band photometry, we calculate the stellar metallicities of individual stars with an expected accuracy of approximately 0.2 dex. From the photometric metallicities we construct a MDF for Leo I containing almost 4000 stars, 5 times more stellar metallicities than have been obtained from the ground. While the metallicity accuracy in our study is lower than spectroscopic measurements, the larger number of data points provides some advantages in looking for rarer components of the population and possible substructure. While the Leo I MDF presented here is a preliminary result, our long term goals are to use the distribution of metallicities of Leo I to constrain the formation and evolution of the system, through and understanding of its chemical evolution.

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245 – Extrasolar Planets: Detection

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

245.01 – **Precision Near-Infrared Radial Velocities**

Peter Plavchan[1], G. Anglada[2], C. Davison[3], P. Gao[4], R. White[3], L. Prato[5], S. Mills[4], D. Ciardi[1], K. von Braun[1], C. Beichman[1], K. Wallace[6], B. Mennesson[6], S. Lin[6]

[1]*NASA Exoplanet Science Institute / Caltech,* [2]*Carnegie Department of Terrestrial Magnetism,* [3]*Georgia State University,* [4]*Caltech,* [5]*Lowell Observatory,* [6]*Jet Propulson Laboratory, Caltech.*

9:00 AM - 6:30 PM

Near-infrared and high-precision have historically been disjoint adjectives to describe precision radial velocity searches. Recent advances have pushed precision in the near-infrared from ~50 m/s with telluric wavelength calibration to ~5 m/s with absorption gas cells. We have built a single gas, near-infrared absorption cell with greater line density and bandpass coverage than recently reported in the literature. We are currently carrying out a survey to detect exoplanets around red, low mass, and young stars. We discuss the current status of our survey, and new near-infrared instrumentation techniques that we are pursuing to complement optical radial velocity work.

245.02 – **CARMENES: A Radial-Velocity Survey for Terrestrial Planets in the Habitable Zones of M Dwarfs**

Andreas Quirrenbach[1], CARMENES Consortium

[1]*Landessternwarte Heidelberg, Germany.*

9:00 AM - 6:30 PM

CARMENES (**C**alar **A**lto high-**R**esolution search for **M** dwarfs with **E**xo-earths with **N**ear-infrared and optical **E**chelle **S**pectrographs) is a next-generation instrument to be built for the 3.5m telescope at the Calar Alto Observatory by a consortium of eleven Spanish and German institutions. Conducting a five-year exoplanet survey targeting ~300 M dwarfs with the completed instrument is an integral part of the project. The CARMENES instrument consists of two separate échelle spectrographs covering the wavelength range from 0.55 to 1.7 µm at a spectral resolution of R = 85,000, fed by fibers from the Cassegrain focus of the telescope. The spectrographs are housed in vacuum tanks providing the temperature-stabilized environments necessary to enable a 1m/s radial velocity precision employing a simultaneous calibration with an emission-line lamp.

245.03 – **Searching for Jupiter Analogues: Detection Limits of the McDonald Observatory Harlan J. Smith 2.7m Telescope Radial Velocity Planet Search**

Caroline Caldwell[1], M. Endl[1], W. Cochran[1], P. J. MacQueen[1]

[1]*University of Texas.*
9:00 AM - 6:30 PM

The McDonald Observatory Planet Search has recorded twelve years of high precision radial velocity measurements. Now it is possible to test the frequency of Jupiter analogues in the database. 81 stars with a twelve-year timeline and no known companions were selected, and simulations were performed to test our sensitivity to the radial velocity signals of Jupiter analogues. Our criteria for a Jupiter analogue are a planetary companion of a sun-like star with a mass between .8 to 4 Jupiter masses, at a distance ranging from 4 to 5.5 AU. A true Jupiter signal is near the limit of our observations at a distance of 5AU with a period of 4330 days, or 11.9 years. The results of these simulations show the database's sensitivity to Jupiter analogues and the frequency of Jupiter analogues. The results demonstrate that the McDonald Observatory Planet Search is a valuable source of high precision radial velocity measurements, and that the continuation of the program is beneficial to the discovery and study of extra solar planets.

245.04 – **A Doppler Search for Planets around Barnard's Star**

Jieun Choi[1], G. Marcy[1], A. Howard[1]

[1]*UC Berkeley.*
9:00 AM - 6:30 PM

Since 1988, we have obtained precise Doppler measurements of Barnard's star at the Lick and Keck Observatories. In particular, there are 199 Keck measurements with a precision of 2.5 m/s from the last 14 years. With this precision and time baseline, we can detect approximately Earth-mass planets for close-in orbits and sub-Jovian-mass planets for orbits of several AU. We have analyzed these Doppler measurements to search for possible signals from planets around Barnard's star. Among the analyses are false alarm probability analysis using periodograms, and a more robust version with Keplerian orbits, which includes orbital eccentricities. We will present the results of this planet-search around Barnard's star and include an assessment of the historic claim for two Jovian planets by Peter van de Kamp.

245.05 – **New Data from the Wesleyan Transiting Exoplanet Program**

Jakob Schaeffer[1], M. C. Johnson[2], S. Redfield[1]

[1]*Wesleyan University,* [2]*University of Texas at Austin.*
9:00 AM - 6:30 PM

We present new data from the Wesleyan Transiting Exoplanet Program (WesTEP). Using the 24" Perkin Telescope at Wesleyan University's Van Vleck Observatory we have observed several new transits allowing for the further refinement of possible transit timing variations (TTVs). The current implementation of an autoguider will hopefully allow us to reach a photometric RMS below our previous benchmark of 1 mmag. In addition we have an expanded target set from previous years, with data on more than thirty-five different transits. A few targets show suggestive signs of TTVs.

245.06 – **The Statistical Significance of Planetary Transit and Occultation Detections at Dome A in Antarctica**

Ryan J. Oelkers[1], D. DePoy[1]

[1]*Texas A&M University.*
9:00 AM - 6:30 PM

The increased discovery of planets through transit detections has created a demand for the characterization of exoplanets. In particular, occultation detections associated with transit events can help determine properties of extra-solar-system planets not possible with other techniques. Unfortunately, many occultation measurements are weakly detected and proper statistical assessment of the significance of the measurement is difficult. We describe a simple approach to determine the statistical significance of an occultation or transit-like detection. We employ a chi-square goodness of fit to multiple eclipse depths and eclipse times over the entire light curve. This allows us to remove the bias associated with an assumed detection time and eclipse depth and thus provide a more accurate description of whether or not the detection could be random or systematic noise or an actual event. Using data from the Antarctic telescope at Dome A (Wang et al. 2011) we are able to confirm the detection of a transit-like event at a statistical level of ~4 sigma. This confirms our technique but also gives confidence in the Dome A telescope's ability to find exoplanets.

245.07 – **Characterizing the Transit Signal Detection Efficiency of the Kepler Pipeline**

Christopher J. Burke[1], J. L. Christiansen[1], J. M. Jenkins[1], P. Tenenbaum[2], S. Seader[2], Kepler Completeness Study Working Group

[1]*SETI Institute / NASA Ames Research Center,* [2]*NASA Ames Research Center.*
9:00 AM - 6:30 PM

Measuring the population distribution of planets from Kepler requires an accurate understanding of the efficiency of the pipeline for detecting transiting planet signals. The Transiting Planet Search (TPS) module of the pipeline is responsible for identifying candidate transit signals. Early versions of TPS operated on a single quarters worth of Kepler data, and the candidate transit signal's significance, so-called Multiple Event Statistic (MES), was the only quantity used to select candidate transit signals for follow up scrutiny in the pipeline. More recent versions of TPS operate on multiple quarters of Kepler data, and additional selection criteria are now employed to select candidate transit signals for follow up. We describe how the selection criteria in TPS have evolved, and their impact on the pipeline efficiency for recovering transit signals. Understanding the selection criteria in TPS is critical for accurately constraining the underlying planet population with Kepler data.

245.08 – **Testing the Accuracy of Ground-Based Transit Timing Observations and Their Uncertainties**

Jacob Gilbert[1], E. L. N. Jensen[2]

[1]*Haverford College,* [2]*Swarthmore College.*
9:00 AM - 6:30 PM

Observations of known transiting exoplanets may help reveal the presence of additional planets in the system, since additional bodies may introduce transit timing variations, or deviations from a strict periodicity of the transits. Many systems have been monitored for this effect; Kepler has clearly detected them in some systems, and there are some tentative detections in the literature using ground-based transit observations. However, the significance of these ground-based detections rests on the question of whether or not the uncertainties on the transit timing measurements are accurate. Gauging the accuracy of transit timing uncertainties is difficult in practice, since successive transits of the same system will not necessarily show the same timing variation, and since it is difficult to know for sure that a given system does not have any intrinsic timing variations. We have begun an observational program to characterize transit timing uncertainties by comparing simultaneous observations of a given transit taken with multiple telescopes. Any pair of observations of a given transit should yield the same transit midpoint, within the uncertainties, *if* those uncertainties are appropriate for the data. We report on our observational program, and on initial analysis of several pairs of transits. The transits were fit using the Transit Analysis Package (TAP) (Gazak et al. 2011) and JKTEBOP (Southworth et al. 2004) codes. Preliminary analysis suggests that accounting for correlated or "red" noise in the fits is essential, as fits assuming only random errors yield error bars that are systematically too small.

We gratefully acknowledge the support of National Science Foundation grant AST-0721386.

245.09 – **Systematic Exoplanet Searches During Predicted Mesolensing Events**

James Matthews[1], R. Di Stefano[1]

[1]*Harvard-Smithsonian Centre For Astrophysics.*
9:00 AM - 6:30 PM

Thus far, exoplanet lensing searches have relied on passive monitoring, in which a field is regularly observed in anticipation of a so-called 'serendipitous event'. This poster focuses on studying individual mesolensing events which can predicted in advance. Each such event can be used to probe for the presence of exoplanets. We have computed the probability of detecting an exoplanet lens by modeling the planet's mass and the characteristics of its orbit. For each event, planets will either be discovered, or we will place limits on possible parameter regimes if they are not. Our work will assist in the design of focused observing programs, and will greatly improve the chances of finding exoplanets through lensing events. In particular, the motion of the M-dwarf VB10 and possible exoplanet companions has been modeled for a predicted mesolensing event in December 2011.

245.10 – **Extracting Binary Orbital Periods Using Timing Analysis of Microlensing Lightcurves**

Xinyi Guo[1], A. Esin[2], R. Di Stefano[3]

[1]*Pomona College,* [2]*Harvey Mudd College,* [3]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

Gravitational microlensing events provide unique opportunities to discover and study binaries. A large number of binary lenses have already been found by the microlensing

surveys. For the majority of these systems, the binary orbital period is much longer than the duration of the lensing event, so orbital motion can be safely ignored. However, a few lenses have already been discovered that show strong evidence of orbital motion on the timescale of the lensing event. We expect that more such systems will be seen in the future. For binaries whose orbital period is comparable to the event duration, the orbital motion can cause the lensing signal to deviate drastically from that of a static binary lens. The most striking property of such lightcurves is the presence of quasi-periodic features, produced as the source traverses the same regions in the rotating lens plane. Those repeated features contain information about the orbital period of the lens. If this period can be extracted, we immediately learn a lot about the lensing system even without performing the detailed lightcurve modeling. However, the relative transverse motion between the source and the lens significantly complicates the problem of period extraction. To resolve this difficulty, we present a modification to the standard Lomb-Scargle periodogram analysis. We test our method for 6 representative binary lens systems and demonstrate its efficiency in correctly extracting binary orbital periods.

245.11 – **Ground-based Detections of Thermal Emission from Hot Jupiters**

Ming Zhao[1], J. Milburn[2], M. Swain[3], J. Monnier[4], S. Hinkley[2], T. Barman[5]

[1]Penn State University, [2]California Institute of Technology, [3]JPL, [4]University of Michigan, [5]Lowell Observatory.

9:00 AM - 6:30 PM

Characterization of hot Jupiter atmospheres allow us to understand the composition, structure, and formation process of these objects. It also paves the way for our eventual characterizations of Earth-like planets. Detections of secondary eclipses of transiting planets in the near-IR provide us information about their atmospheric properties such as temperature-pressure profiles, thermal inversion and chemical composition, and are highly complementary to the Spitzer measurements at longer wavelengths.

We present our recent progress and results from ground-based observations of three hot Jupiters (CoRoT-1b, WASP-12b, and WASP-3b) at secondary eclipses made with the Palomar 200-in and the MDM 2.4m telescopes. Our new guiding software for the WIRC instrument at Palomar 200-in has improved the telescope's guiding precision by a factor of ~5, allowing us to reach much higher photometric precision and thus higher signal-to-noise detections. Our results support the conclusions of previous detections and demonstrate these two telescopes' capability of characterizing hot Jupiters' atmospheres in the near-IR.

245.12 – **Recent Operational Improvements To High Precision Photometric Observations With Warm IRAC**

Sean J. Carey[1], J. Krick[1], J. Ingalls[1], K. von Braun[2], J. Stauffer[1], D. Charbonneau[3], S. Ballard[4], M. Fisher[5], R. Olds[5]

[1]Spitzer Science Center/Caltech, [2]IPAC/Caltech, [3]Harvard University, [4]Harvard-Smithsonian Center for Astrophysics, [5]Lockheed Martin Denver.

9:00 AM - 6:30 PM

We present recent improvements to the data taking for high precision photometric observations with warm IRAC. The IRAC 3.6 and 4.5 μm observations have significant photometric systematics due to a coupling of telescope motions with intra-pixel gain variations. These systematics are being trended with increasingly sophisticated techniques by the community (e.g. Ballard et al. 2010). A significant systematic due to a pointing wobble was reduced by 50% permitting observers to achieve precisions of ~60 ppm (Demory et al. 2011). Most recently, use of the optical peakup instrument aboard Spitzer has been tested to place all IRAC staring mode observations on the same portion of a pixel. These tests have been effective in placing repeated epochs in the same 0.24 by 0.24 arcsec region of a pixel which has a minimal gain variation (sweet-spot).

Preliminary high precision (~10^{-4}) gain maps of the sweet-spots will be presented. Coupled with science data taken at these sweet-spots, the gain maps will improve the ability to remove systematics from photometry. Results from demonstration observations of KOI-069 will be presented. The peakup mode has been tested for targets with V magnitude between 7 and 12.5. In limited testing, peakups using guide stars have been shown effective for stars outside this magnitude range. Full commissioning of the mode is ongoing with the expectation that all high-precision photometric observations will use peakups by the beginning of 2012. Use of the mode can continue as long as Spitzer is operating and should permit photon-limited follow-up and characteriztion of all Kepler discoveries. This work is based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided by NASA through an award issued by JPL/Caltech.

245.13 – **A High-Contrast Adaptive Optics Imaging Search for Giant Planets Around Young M Dwarfs**

Brendan P. Bowler[1], M. C. Liu[1], E. L. Shkolnik[2], M. Tamura[3]

[1]IfA/University of Hawaii, [2]Lowell Observatory, [3]NAOJ, Japan.

9:00 AM - 6:30 PM

Direct imaging planet searches are revealing the architecture of planetary systems at large separations (>10 AU) for the first time. Low-mass stars are generally being neglected from these surveys in part because of the dearth of known nearby young M dwarfs compared to young intermediate- and high-mass stars. As a result, there are few constraints on giant planet formation around low-mass stars at moderate (5-100 AU) separations. We present results from an ongoing high-contrast adaptive optics imaging survey of nearby (<30 pc) young (<300 Myr) M dwarfs with Keck-2/NIRC2 and Subaru/HiCIAO. Our survey is sensitive to planet masses of ~6 MJup and ~2 MJup at separations of 10 AU and 25 AU, respectively, for the median age (100 Myr) and distance (20 pc) of our sample. With a sample size of roughly 70 single M dwarfs, our survey represents the deepest and most extensive imaging search for planets around young low-mass stars to date.

245.14 – **Gemini Planet Imager: From Integration And Test To Planning Observations**

Sandrine Thomas[1], B. Macintosh[2], D. Palmer[2], L. Saddlemyer[3], J. K. Wallace[4], D. Gavel[1], J. Larkin[5], J. Graham[6], R. Doyon[7], B. Oppenheimer[8], S. Goodsell[9], GPI Team

[1]UCO/Lick Observatory, [2]LLNL, [3]Herzberg Institute of Astrophysics, Canada, [4]JPL, [5]UCLA, [6]University of Toronto, Canada, [7]Universite de Montreal, Canada, [8]AMNH, [9]Gemini Observatory.

9:00 AM - 6:30 PM

Achieving higher contrast is an ongoing theme in exoplanet imaging, both from earth and from space. Next-generation instruments such as the Gemini Planet Imager and SPHERE are designed to achieve contrast ratios of 10^6 - 10^7 from the ground; this requires very good static and dynamic wavefront correction as well as very good coronagraphic control of diffraction. GPI is a facility instrument, now in integration and test at the Laboratory for Adaptive Optics in Santa Cruz California. Its first light on the 8-m Gemini South telescope is expected by the end of 2012.

GPI combines a high density MEMS deformable mirror (1700 subapertures), an apodized-pupil Lyot coronagraph and a high-accuracy IR interferometer calibration system.

The instrument is a near-infrared integral field spectrograph (IFS) that will allow detection and characterization of self-luminous extrasolar planets at planet/star contrast ratios of 10-7. One additional feature of the IFS is a polarimetric mode to characterize scattered light from disks. We will discuss the status of the integration and test happening at the University of Santa Cruz California and discuss its scientific capabilities.

245.15 – **Characterizing the Atmospheres of Highly-Irradiated Hot-Jupiters**

Heather Bloemhard[1], M. Creech-Eakman[1], C. Jurgenson[2], F. Santoro[2], M. Hrynevych[1], M. Swain[3], P. Deroo[3], ExoSpec Team

[1]New Mexico Institute of Mining and Technology, [2]Magdalena Ridge Observatory, [3]NASA Jet Propulsion Lab.

9:00 AM - 6:30 PM

Of the more than 500 known exoplanets, the detailed chemical composition of only a handful of exoplanet atmospheres is known. We endeavor to remedy this imbalance by using ground-based spectroscopy, which has been demonstrated to reliably reproduce space-based results (Swain et al., Nature 463, 2010) while obtaining new and unexpected information. Our larger coordinated effort is to systematically characterize transiting exoplanets using a variety of instruments. With this goal in mind, our IRTF/SpeX SXD (0.8-2.4 micron cross-dispersed) observations of WASP-1b and TrES-3b will be used to accomplish two main goals: first, to extend the application of exoplanet ground-based spectroscopy to a wider range of targets than are presently characterized; and second, to probe the temperature structure and begin to characterize the composition of the atmosphere with the transmission and emission spectra of the exoplanets. We will show the steps for our “Model, Correlation, Fit” data reduction method and initial results.

WASP-1b and TrES-3b are both highly-irradiated hot Jupiters with inexplicably inflated radii. This puts them in the pM class of exoplanets. Theory predicts that pM class exoplanets should have a thermal inversion, evidence of H2O, CO, TiO, and VO, and a large day/night contrast; all of which may help explain the inflated radii of these planets (Fortney et al., ApJ, 678, 2008). Thus far, evidence shows that WASP-1b fits this theory (Wheatley et al., submitted to ApJ, 2010). However, TrES-3b does not appear to have the thermal inversion we expect (Croll et al., ApJ, 718, 2010). This apparent contradiction implies that we do not have enough of an understanding about pM class exoplanets. Therefore, determining the structure and composition of the atmospheres of pM class exoplanets is necessary to help us sort among competing theories as to the structure and source of the inflated radius.

245.16 – **On The Frequency Of Hot Jupiters Orbiting F, G, K Dwarfs In The Solar Neighborhood**

Jason Wright[1], G. W. Marcy[2], A. W. Howard[2], J. A. Johnson[3], T. Morton[3], D. A. Fischer[1]

[1]Penn State University, [2]University of California, Berkeley, [3]Caltech.

9:00 AM - 6:30 PM

We estimate the fraction of F, G, K stars in the solar neighborhood hosting hot jupiters as measured by the California Planet Survey from the Lick and Keck planet searches. We compare this with the rate of reported by Howard et al. (2011) for Kepler stars, and with the rate reported from microlensing (Gould et al. 2006) and the HARPS and CORAIE surveys (Mayor et al. 2011). We explore some of the difficulties in estimating this rate from the existing radial velocity data sets and explore why previous works found significantly higher rates, in significant disagreement with Kepler.

245.17 – **Hst Parallax Of XO-3 And Implications For The Structure Of Its Hot Jupiter**

Christopher M. Johns-Krull[1], G. F. Benedict[2], N. Mahmud[1], B. McArthur[2], P. McCullough[3], J. A. Valenti[3]

[1]*Rice Univ.,* [2]*Univ. of Texas at Austin,* [3]*STScI.*

9:00 AM - 6:30 PM

We use HST+FGS to measure the parallax of the transiting planet host star XO-3. Our parallax measurement, with a precision of 0.2 mas, and resulting distance to XO-3 constrains the radius of the star, thereby providing the most accurate radius determination to date for the massive extrasolar planet (XO-3b) in orbit around XO-3. The result allows us to critically test current giant extrasolar planet structure models. The implied radius for XO-3b is smaller than previous determinations, bringing the size of XO-3b more in line with models which include only insolation by the parent star. As a result, their may be no need to invoke heating that may be produced inside XO-3b by tides raised on the planet as it moves through its 3.2 d eccentric (e ~ 0.22) orbit.

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246 – Evolution of Galaxies I

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

246.01 – **Measurement of Galactic Logarithmic Spiral Arm Pitch Angle Using Two-Dimensional Fast Fourier Transform Decomposition**

Benjamin L. Davis[1], J. C. Berrier[1], D. W. Shields[1], J. Kennefick[1], D. Kennefick[1], M. S. Seigar[2], C. H. S. Lacy[1], I. Puerari[3]

[1]*University of Arkansas,* [2]*University of Arkansas at Little Rock,* [3]*National Institute of Astrophysics, Optics and Electronics, Mexico.*

9:00 AM - 6:30 PM

A logarithmic spiral is a prominent feature appearing in a majority of observed galaxies. This feature has long been associated with the traditional Hubble classification scheme, but historical quotes of pitch angle of spiral galaxies have been almost exclusively qualitative. We have developed a methodology, utilizing Two-Dimensional Fast Fourier Transformations of images of spiral galaxies, in order to isolate and measure the pitch angles of their spiral arms. Our technique provides a quantitative way to measure this morphological feature. This will allow the precise comparison of spiral galaxy evolution to other galactic parameters and test spiral arm genesis theories. In this work, we detail our image processing and analysis of spiral galaxy images and discuss the robustness of our analysis techniques. The authors gratefully acknowledge support for this work from NASA Grant NNX08AW03A.

246.02 – **Elucidating the Spectroscopic Division of Globular Clusters in the Andromeda Galaxy**

Suk-Jin Yoon[1], S. Kim[1], C. Chung[1]

[1]*Yonsei Univ., Korea, Republic of.*

9:00 AM - 6:30 PM

Recent spectroscopy of the nearest giant galaxy M31 (the Andromeda galaxy) with unprecedented precision witnessed a clear division of old globular clusters (GCs) in their spectral characteristics. The GC dichotomy in galaxies, so far asserted mainly by photometric color bimodality, is widely taken as the presence of two distinct metallicity subpopulations, and forms a critical backbone of various galaxy formation theories. However we find that, without having to invoke two separate GC subgroups, the spectroscopic division of M31 GCs emerges simply due to the highly nonlinear nature of their stellar mixtures as a function of metallicity. Our findings give a new insight into the structure of GC systems in galaxies, and could greatly simplify theories of galaxy formation.

246.03 – **Spitzer IR Colors and ISM Distributions of Virgo Cluster Spirals**

Jeffrey D. Kenney[1], I. Wong[2], Z. Kenney[1], E. Murphy[3], G. Helou[4], J. Howell[4]

[1]*Yale Univ.,* [2]*CSIRO, Australia,* [3]*Carnegie Observatories,* [4]*Spitzer Science Center.*

9:00 AM - 6:30 PM

IRAC infrared images of 44 spiral and peculiar galaxies from the Spitzer Survey of the Virgo Cluster help reveal the interactions which transform galaxies in clusters. We explore how the location of galaxies in the IR 3.6-8μm color-magnitude diagram is related to the spatial distributions of ISM/star formation, as traced by PAH emission in the 8μm band. Based on their 8μm/PAH radial distributions, we divide the galaxies into 4 groups: normal, truncated, truncated/compact, and anemic. Normal galaxies have relatively normal PAH distributions. They are the "bluest" galaxies, with the largest 8/3.6μm ratios. They are relatively unaffected by the cluster environment, and have probably never passed through the cluster core. Truncated galaxies have a relatively normal 8μm/PAH surface brightness in the inner disk, but are abruptly truncated with little or no emission in the outer disk. They have intermediate ("green") colors, while those which are more severely truncated are "redder". Most truncated galaxies have undisturbed stellar disks and many show direct evidence of active ram pressure stripping. Truncated/compact galaxies have high 8μm/PAH surface brightness in the very inner disk (central 1 kpc) but are abruptly truncated close to center with little or no emission in the outer disk. They have intermediate global colors, similar to the other truncated galaxies. While they have the most extreme ISM truncation, they have vigorous circumnuclear star formation. Most of these have disturbed stellar disks, and they are probably produced by a combination of gravitational interaction plus ram pressure stripping. Anemic galaxies have a low 8μm/PAH surface brightness even in the inner disk. These are the "reddest" galaxies, with the smallest 8/3.6μm ratios. The origin of the anemics seems to a combination of starvation, gravitational interactions, and long-ago ram pressure stripping.

246.04 – **Extragalactic Science With Kepler**

Michael N. Fanelli[1], P. Marcum[1]

[1]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

Although designed as an exoplanet and stellar astrophysics experiment, the Kepler mission provides a unique capability to explore the essentially unknown photometric stability of galactic systems at millimag levels using Kepler's blend of high precision and continuous monitoring. Time series observations of galaxies are sensitive to both quasi-continuous variability, driven by accretion activity from embedded active nuclei, and random, episodic events, such as supernovae. In general, galaxies lacking active nuclei are not expected to be variable with the timescales and amplitudes observed in stellar sources and are free of source motions that affect stars (e.g., parallax). These sources can serve as a population of quiescent, non-variable sources, which may be used to quantify the photometric stability and noise characteristics of the Kepler photometer.

A factor limiting galaxy monitoring in the Kepler FOV is the overall lack of detailed quantitative information for the galaxy population. Despite these limitations, a significant number of galaxies are being observed, forming the Kepler Galaxy Archive. Observed sources total approximately 100, 250, and 700 in Cycles 1-3 (Cycle 3 began in June 2011). In this poster we interpret the properties of a set of ~20 galaxies monitored during quarters 4 through 8, their associated light curves, photometric and astrometric precision and potential variability. We describe data analysis issues relevant to extended sources and available software tools. In addition, we detail ongoing surveys that are providing new photometric and morphological information for galaxies over the entire field. These new datasets will both aid the interpretation of the time series, and improve source selection, e.g., help identify candidate AGNs and starburst systems, for further monitoring.

246.05 – **Publicly Available Database : Improved Spectral Line Measurements In SDSS DR7 Galaxies**

Kyuseok Oh[1], M. Sarzi[2], K. Schawinski[3], S. K. Yi[1]

[1]*Yonsei University, Korea, Republic of,* [2]*University of Hertfordshire, United Kingdom,* [3]*Yale University.*

9:00 AM - 6:30 PM

We present a new database of absorption and emission line measurements based on the Sloan Digital Sky Survey 7th data release for the galaxies within a redshift of 0.2. Our work makes use of the publicly available penalized pixel-fitting(pPXF) and GANDALF codes, aiming to improve the existing measurements for stellar kinematics, the strength of various absorption-line features, and the flux and width of the emissions from different species of ionized gas.

The absorption line strengths measured by SDSS pipeline are seriously contaminated by emission fill-in. We effectively separate emission lines from absorption lines. For instance, this work successfully extract [NI] doublet from Mgb and it leads to more realistic result of alpha enhancement on late-type galaxies compared to the previous database. Besides accurately measuring line strengths, the database provides new parameters that are indicative of line strength measurement quality. Users can build a subset of database optimal for their studies using specific cuts in the fitting quality parameters as well as empirical signal-to-noise. Applying these parameters, we found ‘hidden’ broad-line-region galaxies and they turned out to be Seyfert I nuclei that were not picked up as AGN by SDSS.

The database is publicly available at http://gem.yonsei.ac.kr/ossy

246.06 – **Empirical Constraints on the Coevolution of Supermassive Black**

Holes and their Host Spheroids

Gongjie Li[1], C. Conroy[1], A. Loeb[1]

[1]*Harvard.*

9:00 AM - 6:30 PM

We investigate the evolution of the M_{BH}-σ relation by examining the relationship between the intrinsic scatter in the M_{BH}-σ relation and galaxy bolometric nuclear luminosity, the latter being a probe of the accretion rate of the black hole (BH). Our sample is composed of galaxies with classical bulges when possible, of which 38 have dynamically measured BHs masses, and 17 have BHs masses measured by reverberation mapping. In order to obtain the bolometric nuclear luminosity for galaxies with low nuclear luminosity, we convert the X-ray nuclear luminosity measured by Chandra to bolometric luminosity. We find that the scatter in the M_{BH}-σ relation is uncorrelated with nuclear luminosity over seven orders of magnitude in luminosity, with the high luminosity end approaching the Eddington luminosity. This suggests at the present epoch galaxies evolve along the M_{BH}-σ relation. This conclusion is consistent with the standard paradigm that BHs grow contemporaneously with their host stellar spheroids.

246.07 – **The Star Formation History of a Post-starburst Galaxy from SDSS Data Release 7**

Ryan Sanders[1], E. Hooper[2], M. Wolf[2], C. Tremonti[2]

[1]*University of Louisville,* [2]*University of Wisconsin-Madison.*

9:00 AM - 6:30 PM

We discuss studies on the E+A galaxy J0754+1648 from SDSS Data Release 7. The stages of galaxy mergers are well established, but the time scales of the transition between phases are not well understood. We look into the star formation history of this galaxy using deep optical spectra acquired on the WIYN 3.5-meter telescope at KPNO with the Sparsepak IFU on the bench spectrograph. The galaxy was chosen from a sample of E+A galaxies which show extended or variable radio emission indicating possible ongoing or recent AGN activity. The galaxy displays a highly disturbed morphology indicating a recent merger, as well as showing both poststarburst and starburst spectroscopic signatures in different regions. We estimate star formation rates using emission line flux measurements, providing a lower limit for the total star formation rate in the galaxy. We use the R23 ratio to roughly estimate metallicity. We fit simple stellar populations to the continuum using the Bruzual and Charlot 2003 models to estimate stellar population ages in different regions of the galaxy. We have 1.4 GHz radio data from FIRST which suggests the possibility of an AGN along with large amounts of [OIII] flux in fibers near the peak radio emission. The fibers showing a poststarburst spectroscopic signature also lie in the vicinity of the peak radio emission. We also see evidence of possible gas outflow in this region. The galaxy shows a large amount of ongoing star formation in regions farther removed from the possible AGN. Overall, the galaxy appears to be transitioning between the starburst and poststarburst phase. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

246.08 – **Spatially Distributed Stellar Populations in Post-Starburst Galaxies Containing Radio AGN**

Marsha J. Wolf[1], E. J. Hooper[1]

[1]*Univ. of Wisconsin, Madison.*

9:00 AM - 6:30 PM

We are studying the timing of galaxy merger induced star formation and AGN activity. Here we present initial results on the spatially distributed stellar populations in a sample of post-starburst galaxies with radio properties that suggest ongoing or recent AGN activity after the galaxies have largely stopped forming stars. Many of these galaxies show morphological evidence of mergers or significant interactions. To investigate the potential connection between AGN activity and star formation history, we have nearly completed a vigorous observing campaign on the WIYN telescope including deep optical spectra obtained with the SparsePak integral field unit and near infrared images from the WIYN High Resolution Infrared Camera (WHIRC). The combination of deep exposures and wide spectral coverage allows us to trace the age and metallicity history of the stars in different parts of the galaxies since the beginning of the merger/major interaction. A concurrent program of multi-frequency radio observations allows us to potentially age date the AGN activity. The timelines of these two events will place constraints on the connections between the fueling and truncation of supermassive black hole growth and star formation in the host galaxies.

246.09 – **A Local Baseline for the Black Hole Mass Scaling Relations for Active Galaxies. II. Stellar Kinematics: Results and Practical Guidelines for Future Studies**

Chelsea Harris[1], V. Bennert[1], T. Treu[1]

[1]*University of California Santa Barbara.*

9:00 AM - 6:30 PM

We present the latest results from an ongoing comprehensive survey of 113 local type-1 AGN selected from the SDSS database. The goal is to obtain a more accurate measurement of the slope, intercept, and scatter correlations of the between central black hole mass and host bulge luminosity and stellar velocity dispersion. To meet this goal we collected at the Keck Telescope high signal to noise ratio and spatially resolved long slit spectra, suitable to measure rotation curves and bulge dispersion profiles. In addition to improving the calibration of the local correlations by reducing uncertainties in host galaxy properties, a main goal of our program is to apply what we learn in the local universe to minimize systematic uncertainties in the study of their cosmic evolution. Results from a pilot study are given in paper I (Bennert et al. 2011).

We present here the full spectroscopic sample and stellar kinematics measurements, which are challenging owing to the presence of AGN emission. To produce the most accurate measurements and investigate potential biases, we focus on three different spectroscopic regions, including the strong stellar features: CaHK, MgIb, and CaII IR triplet. We achieve the following goals: (1) cross-calibrate the three spectroscopic regions, using the Ca triplet as a benchmark; (2) determine the reliability of each region as a function of S/N ; (3) determine the reliability of the regions when various strong stellar absorption features are excluded from a given region; and (4) estimate the success rate of measuring sigma_stellar from the Ca H+K region based on simple parameters available for many target candidates in the SDSS survey catalogue. We investigate each issue both as a function of offset from galactic center and also for synthetic spatially unresolved spectroscopy, mimicking what would be observed in the SDSS-fibers or for high redshift sources.

246.10 – **The Morphologies of Double-peaked Active Galactic Nuclei**

James Diekmann[1]

[1]*UT Austin.*

9:00 AM - 6:30 PM

We report the morphologies of double-peaked active galactic nuclei (DPAGN) in the Sloan Digital Sky Survey. DPAGN are active galaxies that have double-peaked [O III] emission lines that indicate they are good candidates for dual AGN. Dual AGN are produced when two galaxies merge, and each galaxy has a central supermassive black hole (SMBH) powering an AGN. The morphological results suggest that DPAGN occur preferentially in elliptical galaxies, which is consistent with expectations that dual AGN are produced in merger-remnant galaxies with elliptical morphologies. Overall, understanding the structure of a galaxies hosting DPAGN can be used to probe formation scenarios of dual AGN and dynamics of SMBHs in mergers.

246.11 – **The Mass-Dependent Evolution of Galaxies Through the Green Valley**

Jerome J. Fang[1], S. M. Faber[1], S. Salim[2]

[1]*University of California, Santa Cruz,* [2]*University of Indiana.*

9:00 AM - 6:30 PM

Galaxies populate a bimodal distribution in color-mass space, with star-forming objects residing in the blue cloud and quiescent galaxies located in the red sequence. The transition region between these two populations is known as the green valley. Utilizing data from SDSS and GALEX, we study how galaxies evolve through the green valley as a function of stellar mass. Our diagnostics combine integrated quantities (e.g., color and size) with fiber-based measurements (e.g., spectral indices and line fluxes), allowing us to probe how star formation shuts down in green valley galaxies. In particular, we focus on the relationship between integrated UV-optical color and fiber emission line strength. The distribution of galaxies in this parameter space changes as a function of mass, which we interpret as evidence for mass-dependent mechanisms of quenching star formation. We estimate the relative fraction of green valley galaxies likely undergoing each quenching mode. In doing so, we find that contamination in the green valley due to dusty, star-forming galaxies is significant and must be taken into account when determining number counts of bona fide transition objects.

246.12 – **USGC U579: The Group of Galaxies Surrounding HCG 069**

Michael Pinkard[1], G. L. Hoffman[1]

[1]*Lafayette College.*

9:00 AM - 6:30 PM

The properties of USGC U579, the loose group of 110 galaxies roughly centered on Hickson Compact Group 069, are studied to assess the effect of the group environment on the galaxies. Data are drawn from the ongoing Arecibo Legacy Fast ALFA (ALFALFA) Survey of neutral hydrogen, from the Sloan Digital Sky Survey (SDSS) and from the NASA/IPAC Extragalactic Database (NED). Methods of determining the dynamical mass of the group are explored, as well as methods for determining the baryonic mass of the group using combined gas and stellar mass values, where the gas mass is scaled from the neutral hydrogen mass calculated from ALFALFA data, and the stellar mass is calculated from SDSS and NED data. An initial total mass to baryonic mass ratio of about 144 is found, a reasonable ratio considering the size of the group. Hydrogen deficiency is explored within the group and is not found to be statistically significant when the inner and outer portions of the group are compared, nor when HCG 069 is compared to the rest of the group. As part of the broader Undergraduate ALFALFA Team project group this work furthers investigation of galaxy formation and evolution. The Undergraduate ALFALFA Team has been sponsored by NSF grants AST-0724918, AST-0725267, AST-0725380, AST-0902211 and AST-0903394.

246.13 – **Star-Forming HI-Rich Galaxy Groups in the Local Universe**

Gerhardt R. Meurer[1], S. Sweet[2], M. J. Drinkwater[2], V. Kilborn[3], K. Bekki[1], SINGG

[1]*University of Western Australia / ICRAR, Australia,* [2]*University of Queensland, Australia,* [3]*Swinburne University, Australia.*

9:00 AM - 6:30 PM

Follow-up H-alpha observations of the HIPASS survey typically show one, and sometimes two star forming galaxies within the 15 arc-minute beam of the Parkes 64m HI detections. In our Survey of Ionization in Neutral Gas Galaxies (SINGG) we found 15 cases of HIPASS sources containing four or more Emission Line Galaxies (ELGs). In the most extreme case we found groups with at least 9 ELGs. Most of the ELGs found in these groups are very different from those in the field. The larger more obvious galaxies are usually distorted, and typically have a few dwarf galaxy companions. These dwarfs typically have very odd compact morphologies, some being barely distinguishable from a single HII region, yet not obviously attached to a host. Here we highlight some of the properties of these groups and the galaxies they contain. We outline our current work on these systems including follow-up integral field unit optical spectroscopy, HI synthesis imaging and simulation work to understand these peculiar dense star forming groups.

246.14 – **Multiwavelength Observations of an Assembling Galaxy Cluster : AGN Content**

Emily E. Freeland[1], K. Tran[1]

[1]*Texas A&M University.*

9:00 AM - 6:30 PM

Galaxy groups are increasingly recognized as a key environment for transforming galaxy morphologies and star formation rates. Super-Group 1120-12 consists of four virialized groups at z~0.37 that will merge and form a cluster comparable in mass to Coma by the current epoch. Using multiwavelength (X-ray, UV, Optical, 24 micron, Radio) imaging and spectroscopic data we identify numerous AGN, star-forming, and composite galaxies and compare their frequency to that found in cluster and field environments.

246.15 – **Linking ULIRGS and Quasars: Looking for Predicted Morphological Signatures of AGN Feedback**

Nicole Steward[1], E. K. S. Hicks[1], R. I. Davies[2]

[1]*University of Washington,* [2]*MPE, Germany.*

9:00 AM - 6:30 PM

Current leading theories propose a galactic evolutionary tract linking ultra-luminous infrared galaxies (ULIRGS) with quasars via a ‘blowout’ stage, during which the energy output resulting from accretion of material onto the central black hole expels the gas obscuring the central quasar. However, this phase would be short-lived and therefore difficult to directly observe, meaning evidence that this is indeed how galaxies evolve is scare. We obtained 2-D K-band integral field data with SINFONI on the VLT for a sample of six quasars that are divided into 'pre-' and 'post-blowout' by comparing their ratios of infrared luminosity to the luminosity of the optical 'big blue bump’. By measuring the spatial distribution and column density of the warm molecular gas on scales down to less than 1 kpc we determine if a correlation exists between these quantities and the ‘pre-’ an ‘post-blowout’ subsamples as predicted by evolutionary models.

246.17 – **Spitzer Infrared Spectrograph Observations of Infrared-Luminous Galaxies at Moderate Redshift: Diagnostics of AGN and Star Formation**

Heath V. Shipley[1], C. Papovich[1], A. Dey[2], B. Jannuzi[2], G. Rieke[3], B. Weiner[3]

[1]*Texas A&M University,* [2]*National Optical Astronomy Observatory,* [3]*University of Arizona.*

9:00 AM - 6:30 PM

We use mid-Infrared (MIR) spectroscopy from Spitzer to study star-formation and AGN processes in 65 IR-luminous galaxies at $0.02 < z < 0.6$. The MIR spectra cover wavelengths 5-38μm, spanning the strongest polycyclic aromatic hydrocarbon (PAH) features and other important diagnostic lines. Our sample of galaxies spans the full range of rest-frame (u-r) optical color with F(24μm) > 1.2 mJy, which corresponds to total IR luminosity, $L(IR)=10^{10}$-$10^{12}L\odot$, with a median $L(IR) \sim 10^{11}L\odot$. We select a subset of galaxies with Spitzer IRAC 3.6-8.0μm colors indicative of warm dust heated by an AGN. Compared to IR-luminous galaxies with no indications of AGN, these IRAC-selected AGN show weaker PAH emission, which we attribute to an increase in MIR continuum from the AGN. We find that the luminosity in the PAH features correlates strongly with [Ne II] λ12.8μm emission in both the AGN and non-AGN subsamples. We find no measurable difference between the luminosity ratios of ionized and neutral PAHs, specifically the 7.7-to-11.3μm PAH ratio. This suggests that the AGN do not preferentially excite or destroy the PAH molecules on galaxy-wide scales, and in all IR-selected galaxies the PAH luminosity correlates strongly with the total SFR. A small subset of galaxies show a strong excess of [O IV] λ25.9μm emission for their PAH emission, indicating the presence of heavily-obscured AGN in galaxies. We compare the position of both the IR-AGN to other galaxies on an optical color-magnitude relation. The IRAC-selected AGN populate a range of color, primarily in the ``green valley'', implying their hosts are a mix of starburst and post-starburst galaxies. The [O IV]-excess objects in our sample lie toward the red end of the ``green valley''. Given their placement on the color-magnitude diagram, and their weak PAH emission, we conclude their IR luminosity is dominated by processes associated with the AGN.

246.18 – **Recovering Galaxy Stellar Population Properties From Spectral Energy Distribution Fitting**

Janine Pforr[1], C. Maraston[1], C. Tonini[2]

[1]*Institute of Cosmology and Gravitation, University of Portsmouth, United Kingdom,* [2]*Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Australia.*

9:00 AM - 6:30 PM

A robust determination of the galaxy stellar population properties is imperative for galaxy formation and evolution studies. We explore the dependence of these properties derived from broad-band spectral energy distribution fitting - such as stellar mass, etc. - on a variety of parameters, such as star formation histories, initial mass function, dust reddening, wavelength coverage etc.. using mock galaxies obtained with semi-analytic models. We confirm our earlier results that usually adopted τ-models tend to overestimate star formation rates and underestimate stellar masses.

We show that - for mock star-forming galaxies - galaxy properties can be well determined simultaneously only when one uses the right setup and wavelength coverage, i.e. the correct star formation history, which is the case for inverted-τ models at high-z (Δ log M* =~0.04 dex). Since the right star formation history is normally unknown, we quantify the offsets generated by adopting standard fitting setups. Stellar masses and ages are generally underestimated. For setups with a variety of star formation histories the median mass recovery at z~ 2-3 is as decent as ~0.1 dex. At z~0.5 the stellar mass can be underestimated by as much as ~0.6 dex because of the variety of possible star formation histories and ages. Excluding reddening from the fitting improves the result by avoiding unrealistically young and dusty solutions. Hence, stellar masses are underestimated less (~0.3 dex at z~0.5). The recovery of properties is substantially better for mock passive galaxies (e.g. Δ log M* ~0.01 dex). The wavelength coverage adopted in the fitting is crucial; a coverage from the rest-frame UV to the rest-frame near-IR appears to be optimal. We quantify the effect of narrowing the wavelength coverage which can be useful for planning observational surveys. We provide simple scaling relations that allow the transformation of stellar masses obtained using different fitting setups.

246.19 – **Paschen Alpha Dynamics of Local LBG analogs: A Low-Redshift Test of High-Redshift Assumptions**

Kelsey Braxton[1], E. K. S. Hicks[1], A. Baker[2], W. Kropat[1], N. M. Forster Schreiber[3]

[1]*University of Washington,* [2]*Rutgers,* [3]*MPE, Germany.*

9:00 AM - 6:30 PM

Using integral field data from SINFONI on VLT we measure the Paschen alpha emission in six nearby (mean z=0.16) galaxies with high UV luminosities and surface brightnesses which define them as local analogs of z~3 Lyman Break Galaxies (LBGs). From these data we spatially resolve the distribution and kinematics, velocity and velocity dispersion, of the gas to test if nebular emission lines trace the mass distribution in this galaxy population as is assumed in high redshift studies. Using the method of kinemetry we also characterize the kinematics of the gas and quantify deviations from perfect disk rotation, which allows us to classify each galaxy as a disk- or merger-like system. Future work will include a comparison of the nebular gas properties with that of the molecular gas measured by CO(1-0) emission at comparable spatial resolution to assess the validity of popular but critical assumptions about this galaxy population: that nebular emission lines are reliable kinematic tracers, that gas mass can be inferred from (unobscured) star formation rate and the local Schmidt law, and that the CO-to-H2 conversion factor is the same as that derived in the Milky Way.

246.20 – **The Emission Line Luminosity Functions Of hα, OII, And OIII At $0<z<1.7$ As Seen By PEARS**

Norbert Pirzkal[1], S. Malhotra[2], J. E. Rhoads[2], C. Ly[1], B. Rothberg[1], A. Straughn[2], G. Meurer[3]

[1]*STScI,* [2]*ASU,* [3]*UWA, Australia.*

9:00 AM - 6:30 PM

Emission line galaxies are a powerful tracer of star formation in the Universe. By computing and examining the shape of the line luminosity function (the number density per logarithmic interval in line luminosity) we can study how star formation occurred in star forming galaxies. We can also look for variation in the line luminosity function of these objects as a function of redshift to look for evidence of evolution in the way star formation took place over the last few billion years. We present emission line luminosity functions obtained using the slitless grism survey data of the PEARS projects. We applied the PEARS-2D technique to pinpoint the location of line emission in field galaxies and hence were able to extract spectra of individual line emission regions in the PEARS fields, which covers a large fraction of the GOODS-N and GOODS-S fields.

We detected lines with fluxes as low as 5. 10^{-18} erg/s/cm^2 and identified Hα, OIII, OII, Hg and Lyα lines, over a redshift range of 0<z<7.2. Most of the lines we identified are Hα (213 lines, 0<z<0.5), OIII (297 lines, 0.2<z<1.0) and OII (196 lines, 0.6<z<1.7). We identified single line emission regions, multiple line emissions regions as well as several cases of multiple star forming regions in single galaxies. We present the luminosity functions for Hα, OII, and OIII computed across these relatively broad redshift ranges and conclude by examining the evolution of the Hα luminosity function from z=0.5 to z=0, the OII luminosity function from z=1.7 to z=0.6, and the OIII luminosity function from z=1.0 to z=0.2.

246.21 – **Predicting Future Space-Based Slitless Spectroscopic Surveys Using the WFC3 Infrared Spectroscopic Parallels (WISP)**

James W. Colbert[1], H. Teplitz[2], M. Malkan[3], H. Atek[2], N. Ross[3], B. Siana[4], A. Henry[5], P. McCarthy[6], A. Bunker[7], C. Scarlata[8]

[1]Spitzer Science Center, [2]IPAC/Caltech, [3]UCLA, [4]UC Riverside, [5]UC Santa Barbara, [6]Carnegie Observatories, [7]Oxford, United Kingdom, [8]University of Minnesota.

9:00 AM - 6:30 PM

Future space telescopes are likely to make extensive use of slitless grism spectroscopy in the near-IR over large areas of sky. Both ESA's recently selected Euclid mission and the WFIRST mission being studied by NASA plan slitless spectroscopic surveys to obtain redshifts over thousands of square degrees. The HST WFC3 camera has two near-infrared grisms, G102 and G141, covering 0.8-1.6 microns, making it perfect the perfect laboratory for predicting what these future missions will find. We present results from the WFC3 Infrared Spectroscopic Parallels (WISP) program, which has been taking deep WFC3 observations using both grisms at random locations across the sky in parallel with primary COS observations. The WISP survey presently consists of more than 150 fields, covering ~700 square arcminutes, reaching fluxes of 5 x 10^{-17} ergs/s/cm^2. We will present completeness corrected number counts, luminosity functions, and predicted counts for the proposed future missions. We will also discuss the issue of line identification of the emission lines, particularly H-alpha and [OIII]5007 which often have similar fluxes and equivalent widths.

246.22 – **Observing Star Formation Quenching In Action: A Powerful [ne V] Outflow In A Post-starburst Radio Galaxy**

John Chisholm[1], C. Tremonti[1], T. Heckman[2], Y. Chen[1], G. Kauffmann[3], K. Schawinski[4], M. Strauss[5]

[1]University of Wisconsin, [2]John Hopkin's University, [3]MPA, Germany, [4]Yale, [5]Princeton.

9:00 AM - 6:30 PM

A crucial question in galaxy evolution is how star formation is quenched to form massive red sequence galaxies. We have recently identified an unusual post-starburst radio galaxy at z = 0.94 in the SDSS-III's Baryon Oscillation Spectroscopic Survey. The galaxy has anomalously strong [OIII], [Ne III] and [Ne V] emission lines, with velocities extending out to -3000km/s. The SDSS-III spectrum and imaging data lead us to suggest two possible scenarios for these anomalous lines: the end of a relatively short lived, but extremely energetic phase of AGN-driven gas expulsion, or a chance alignment of an AGN radio jet and a gas-rich companion. We analyze longslit spectra obtained with the Robert Stobie Spectrograph on the South African Large Telescope to help distinguish between the proposed scenarios and gain insights into the physical mechanisms responsible for AGN-driven gas expulsion.

246.23 – **A Magnified View Of Star Formation At z=0.9 From Two Lensed Galaxies**

Alice Olmstead[1], J. Rigby[2], S. Veilleux[1]

[1]University of Maryland, [2]Goddard Space Flight Center.

9:00 AM - 6:30 PM

We present new narrow-band Hα imaging from the Hubble Space Telescope of two z=0.91 galaxies that have been lensed by foreground galaxy cluster Abell 2390. These data provide a magnified look at the morphology of star formation at an epoch when the global star formation rate was still high. From the continuum subtracted Hα image, we characterize the morphology of star formation in the source plane, using techniques commonly applied to local galaxies, but not possible for distant galaxies unless lensed. We compare the distribution of star formation as traced by Hα to the broad-band colors from filters at 555, 814, and 1250 nm. Finally, we compare the star formation rates measured three different ways: from Hα, from the mid-IR [Ne II] and [Ne II] lines, and from the mid- to far-infrared spectral energy distributions.

246.24 – **Star Formation and AGN Activity in Ultraluminous Infrared Galaxies at z > 1.15**

Vivienne Baldassare[1], J. Kartaltepe[2]

[1]Hunter College, [2]National Optical Astronomy Observatory.

9:00 AM - 6:30 PM

We studied active galactic nucleus (AGN) activity and star formation in a sample of 52 luminous and ultraluminous infrared galaxies ((U)LIRGs) with 1.17 < z < 1.602 and $L_{IR} > 10^{11.5}$ L_{solar}. ULIRGs get their extreme infrared luminosities from the heating of dust by star formation and/or AGN. Studies done in the local universe have revealed that all local ULIRGs are mergers (Sanders & Mirabel 1996), and have proposed evolutionary schemes in which early merger stages are dominated by starbursts, intermediate merger stages are dominated by starburst-AGN composite objects, and late merger stages are dominated by AGN (Yuan et al. 2010). They have also shown that most ULIRGs with $L_{IR} > 10^{12.4\text{-}12.5}$ L_{solar} appear AGN-like (Tran et al. 2001). We used near infrared spectroscopy in order to determine whether these trends extend to high redshift, utilizing the [NII]/H-alpha and [OIII]/H-beta line ratios to plot our objects on a BPT diagram which classifies them as star forming, AGN, or composite. We find that many of the objects in our sample show evidence of mergers or interactions, and that all objects in our sample with $L_{IR} > 10^{12.5}$ L_{solar} are AGN or composite objects.

Vivienne Baldassare 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 and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

246.25 – **The Evolution of Lyman Break Galaxies Between z=1.5 and z=5.0**

Nimish P. Hathi[1], P. J. McCarthy[1], S. H. Cohen[2], R. E. Ryan Jr.[3], R. A. Windhorst[2], H. Yan[4], M. J. Rutkowski[2], A. M. Koekemoer[3], R. W. O'Connell[5], WFC3 SOC

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9:00 AM - 6:30 PM

The high sensitivity of the Wide Field Camera 3 (WFC3) on the Hubble Space Telescope has made it possible to identify and study Lyman break galaxies (LBGs) at z>7, when the universe was only about 650 Myr old. However, it is very difficult to understand the details of their stellar populations using current space and ground-based telescopes. Their great distances and faint fluxes make it extremely difficult for any kind of spectroscopic studies, and the limited high resolution photometry also makes it challenging to investigate their Spectral Energy Distributions (SEDs). The peak epoch of global star-formation rate, z=1.5-3.0, is now accessible with the WFC3 UVIS channel and is not affected by above mentioned limitations. The accuracy of the SED fitting with a large number of photometric data points including rest-frame optical observations, will tremendously increase our physical understanding of LBGs. We will present results from our SED analysis of LBGs at z=1.5-5.0 and infer possible evolutionary trends by comparing their physical properties such as stellar mass, stellar age, dust attenuation, and star-formation rate.

This work 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 #11359 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.

246.26 – **The Radical Transformation of Massive Galaxies Since z~2**

Tim Weinzirl[1], S. Jogee[1], C. J. Conselice[2], C. Papovich[3], R. Chary[4], A. Bluck[5], R. Gruetzbauch[2], F. Buitrago[2], R. A. Lucas[6], M. Dickinson[1], A. E. Bauer[7]

[1]University of Texas at Austin, [2]University of Nottingham, United Kingdom, [3]Texas A&M University, [4]U.S. Planck Data Center, [5]Gemini Observatory, [6]Space Telescope Science Institute, [7]Australian Astronomical Observatory, Australia.

9:00 AM - 6:30 PM

While the most massive present-day galaxies are large systems dominated by spheroids of old stars that exhibit little on-going star formation, their progenitors at intermediate redshift are an area of active study. We investigate this issue using one of the largest, most diverse samples of massive galaxies at z=1-3 mapped by the GOODS-NICMOS survey. We find that massive (M*>5×10^{10} M_{sun}) galaxies at z=2-3, when the Universe was ~2-3 billion years old, are radically different in terms of rest-frame optical structure, star formation rate (SFR), and black hole activity. (1) As much as ~40% of massive galaxies at z=2-3 have ultra-compact rest-frame optical sizes (half-light radius <2 kpc), while less than 1% of massive galaxies at z~0 are that small. On average, massive galaxies at z=2-3 are more compact by a factor of 3-4. Furthermore, unlike their local counterparts, a large population of massive galaxies at z=2-3 have shapes, structural properties (Sersic index n<2), and SFR activity that all favor the presence of a massive disky component over a spheroid. (2) Up to 40% of massive galaxies at z=2-3 host active black holes (AGN), which is at least an order of magnitude higher than at z~0. Furthermore, there is a fascinating correlation between structure, SFR, and AGN activity. Most disky structures have a significant (5σ) 24 μm Spitzer

detection, and such disky systems host the highest SFR (53 to 1466 M_{sun} yr^{-1}). Most (~65%) AGN hosts have disky morphologies. Ultra-compact galaxies appear quiescent in terms of AGN activity and SFR. (3) The question of how to transform the massive galaxies present 2-3 Gyr after the Big Bang into modern bulge-dominated E/S0s remains a challenge for the current paradigm of galaxy evolution. We discuss the role of major and minor mergers as well as gas accretion along cosmological filaments.

246.27 – **The Sizes of Passively Evolving Galaxies in the CANDELS Fields**

Russell E. Ryan[1], CANDELS Team

[1]*STScI.*

9:00 AM - 6:30 PM

A report on the size-mass evolution of passively evolving galaxies at z~2, which were selected based on their optical/infrared colors from the CANDELS data. We determine effective radii and Sersic indices using our graphical front-end to GALFIT, which can fit, mask, and modify objects in a fully interactive fashion. We present these structural parameters for the various optical and infrared bands observed by the Hubble Space Telescope. By fitting the observed optical and infrared photometry, we estimate stellar population parameters (such as stellar mass, age, and star formation rate) using a Markov Chain Monte Carlo procedure, which allows for robust estimate of the parameter (co-)variances. We discuss these results in the context of the recently proposed stellar mass-dependent size evolution model.

246.28 – **Investigating the Isolated Early-type Galaxy Selection Criteria**

Alfredo J. Negron-Rivera[1], C. Fuse[1], P. Marcum[2], M. N. Fanelli[3]

[1]*Rollins College,* [2]*NASA Ames Research Center,* [3]*BAER Institute, Nasa Ames Research Center.*

9:00 AM - 6:30 PM

Isolated galaxies provide a means of assessing theories of formation and evolution. Past studies have employed a variety of techniques to obtain samples of isolated elliptical galaxies (IEGs), but the results of these studies have not provided a uniform understanding of IEG properties. Our goal is to examine the set of isolation criteria that yields a uniform sample of the most isolated early-type galaxies with minimal contamination from spiral galaxies. We use the Sloan Digital Sky Survey (SDSS) to identify IEGs in the nearby universe. Redshifts derived from the SDSS spectra permit a robust three-dimensional assessment of the environment surrounding the IEG candidates.

The study examined four criteria for selecting isolated early-type systems: 1. 2D radial separation between IEGs and neighboring galaxies, 2. 3D redshift difference, 3. The neighbor galaxy brightness limit, and 4. the Petrosian ratio (P50/P90), used to extract early-type systems. The examination of the selection criteria allowed us the ability to judge the relative importance of the individual criteria when building samples of IEGs.

The results indicate that multiple selection criteria can be used to create samples of IEGs. Specifically, each search resulted in samples with a population of low- to intermediate-luminosity, bluer than average early-type galaxies. However, some searches yielded samples with colors and luminosities associated with "typical" early-type systems. The selection criteria that identify the largest number of bright, red, isolated early-type systems are ~2.0 Mpc radial separation, a redshift difference between IEG and any neighbor galaxy of Δcz ~300 km s-1, a neighbor galaxy brightness limit of $-18.0 \leq MV \leq -17.0$, and a Petrosian ratio of $0.42 \leq P50/P90 \leq 0.36$.

246.29 – **A Swift X-ray Survey Of The Localization For An Icecube 22-string Candidate Source Of High-energy Neutrinos**

Kyle Conlon[1], D. Fox[1]

[1]*Pennsylvania State University.*

9:00 AM - 6:30 PM

We have carried out an X-ray survey of the region of sky within 30.9′ of a candidate high-energy (E> 1TeV) neutrino source, which we named IC22 J1013.5+1124, using the Swift satellite's X-ray telescope. This source was identified as the most significant single candidate source in the point-source analy- sis of the IceCube neutrino observatory's 22-string science run (May 2007 to April 2008; Abbasi et al. (2009)). As IC22 J1013.5+1124 represents an excess at the 2.2σ level after accounting for all trials, it is not claimed to represent an astro- nomical source of high-energy neutrinos; moreover, the source is not apparent in deeper observations subsequently taken by IceCube in a 40-string configuration (April 2008 to May 2009; Abbasi et al. (2011)). Nonetheless, given the pioneering nature of the facility, the identification of even a relatively low-confidence candi- date the intriguing possibility of using IceCube, in concert with other observato- ries, to identify and study high-energy astronomical objects. Our survey achieves a median exposure of 4440 s over the target region, with 94% of the region having > 2000 s exposure, and reveals 41 X-ray sources, all with high-likelihood counterparts from Sloan Digital Sky Survey (SDSS) imaging. We present our X-ray catalog, comment on the likely nature of the sources and discuss lessons learnd regarding future analyses of candidate "multimessenger" astronomical sources.

246.30 – **Brightest Cluster Galaxy Formation: Models vs Observations**

Shannon MacKenzie[1], A. Pipino[2]

[1]*University of Louisville,* [2]*ETH Zurich, Switzerland.*

9:00 AM - 6:30 PM

We present a study on the formation of the brightest/most massive galaxies in clusters in which we compare predictions by the GalICS semi-analytic model for galaxy formation to observations using the Szabo et al. (2011) SDSS cluster catalogue. The goals of the project are many, for instance to assess the validity of the common assumption that the most massive galaxy is central to its own cluster. In addition, we aim at assessing if the mass (luminosity) difference between the first and the second ranked galaxy correlates with either the status of the clusters (relaxed versus on-going merger) or the age. Preliminary results will be presented.

246.31 – **A Lyman-Alpha Galaxy at Redshift z=6.944**

Pascale M. Hibon[1], J. E. Rhoads[2], S. Malhotra[2], M. Cooper[3], B. Weiner[4]

[1]*Gemini Observatory, Chile,* [2]*Arizona State University,* [3]*University of California, Irvine,* [4]*Steward Observatory, University of Arizona.*

9:00 AM - 6:30 PM

Searching for high redshift galaxies is one of the most active fields of observational cosmology and is essential to characterizing and understanding the formation and evolution of galaxies. Galaxies at redshift 6 are routinely found. Detection of $z\approx7$ galaxies is however still rare. From $z=6.5$ to $z=7$ light dimming due to luminosity distance is 17% and the age of the Universe differs by 172 Myr. At these redshifts, the Universe is thought to be undergoing re-ionization. Lyman-α-emitting galaxies can be used to study cosmological reionization, because resonant scattering of Lyman-α photons should effectively hide them from view in a neutral universe.

We here present a Lyman-α emitting galaxy identified at redshift $z = 6.944$ in the COSMOS field, based on a combination of narrowband imaging and follow-up spectroscopy with the IMACS instrument on the Magellan I Baade telescope.

With a single object spectroscopically confirmed so far, our survey remains consistent with a wide range of Inter-Galactic Medium (IGM) neutral fraction at $z \approx 7$, but further observations are planned and will help clarify the situation. Meantime, the object we present here is only the second Lyman-α-selected galaxy to be spectroscopically confirmed at $z \approx 7$, and is considerably fainter than the previously known $z \approx 7$ LAE (Iye et al. 2006).

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247 – Black Holes

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

247.01 – **The Absence of Radio Emission from the Globular Cluster G1**

J. M. Wrobel[1], J. C. A. Miller-Jones[2], C. O. Heinke[3], G. R. Sivakoff[3], R. E. Miller[3], R. Di Stefano[4], A. K. H. Kong[5], J. E. Greene[6], L. C. Ho[7]

[1]*NRAO,* [2]*Curtin U., Australia,* [3]*U. Alberta, Canada,* [4]*CfA,* [5]*NTHU, Taiwan,* [6]*U. Texas,* [7]*Carnegie.*

9:00 AM - 6:30 PM

The globular cluster G1 in M31 has been suggested as a good candidate to host an intermediate-mass black hole. An excess of dark mass at the cluster center was inferred from studies of the stellar dynamics, and the subsequent detection of both X-ray and radio emission from positions consistent with the cluster core suggested the presence of an accreting black hole. From the ratio of radio to X-ray luminosities, the black hole mass was believed to fall in the range 500-19,000 solar masses, although a variable stellar-mass X-ray binary could not be ruled out owing to the non-simultaneity of the radio and X-ray observations. We therefore made strictly-simultaneous observations in 2011 with Chandra and the Expanded Very Large Array (EVLA) to determine the ratio of radio to X-ray luminosities. The EVLA was in its A configuration, providing a FWHM resolution of 0.4 arcsec near 6 GHz. While the X-ray emission was consistent with the previously-reported level of about $2x10^{36}$ ergs/s (2-10 keV), no radio emission was detected from the cluster to a 5-sigma upper limit of 8 microJy/beam, about 3.5 times lower than the previously-reported radio detection in 2006. We discuss two possible explanations for the dramatic radio non-detection, namely that the radio source in G1 is time-variable, or that the previous 4.5-sigma source was an artifact, possibly caused by the mix of VLA and EVLA electronics in use in 2006. Although our simultaneous measurements in 2011 can constrain the mass of a central black hole through the empirical radio--X-ray--mass relation for accreting systems, the simplest explanation is that the X-ray emission from G1 arises from a low-mass X-ray binary. The NRAO is a facility of the NSF operated under cooperative agreement by AUI.

247.02 – **Determining the Local Black Hole Mass Function from the Pitch Angles of Nearby Spiral Galaxies**

Lucas Johns[1], D. Kennefick[2], J. C. Berrier[2], B. L. Davis[2], D. W. Shields[2]

[1]*Reed College,* [2]*University of Arkansas.*
9:00 AM - 6:30 PM

We present pitch angle measurements of a nearly complete sample of nearby spiral galaxies. Using these results along with the relationship between supermassive black hole mass and the pitch angle of the host galaxy's spiral arms, we have determined the black hole mass function for local spiral galaxies. The pitch angle measurements were obtained by applying a two-dimensional fast Fourier transform to optical images. This technique can be extended to samples of spiral galaxies at higher redshifts in order to investigate how the black hole mass function has changed over time. Funding for this project was provided by NASA and NSF grants.

247.03 – **Numerical Simulations of Optically Thick Accretion onto a Black Hole - Spherical Case**

Joanna Gillespie[1], P. Fragile[1], T. Monahan[1], M. Rodriguez[1]

[1]*College of Charleston.*
9:00 AM - 6:30 PM

Modeling the radiation generated by accreting matter is an important step towards realistic simulations of black hole accretion disks, especially at high accretion rates. To this end, we have recently added radiation transport to the existing general relativistic magnetohydrodynamic code, Cosmos++. However, before attempting to model radiative accretion disks, we have tested the new code using a series of shock tube and Bondi (spherical inflow) problems. The four radiative shock tube tests, first presented by Farris et al. (2008), have known analytic solutions, allowing us to calculate errors and convergence rates for our code. The Bondi problem only has an analytic solution when radiative processes are ignored, but is interesting because it is closer to the physics we are ultimately interested in. In our simulations, we include Thomson scattering and thermal bremsstrahlung in the opacity, focusing mostly on the super-Eddington regime. Unlike accretion onto bodies with solid surfaces, super-Eddington accretion onto black holes does not produce super-Eddington luminosity. In our examples, despite accreting at up to one hundred times the Eddington rate, our measured luminosity is always several orders of magnitude below Eddington.

247.04 – **Mesoscale and Emergent Phenomena in Magnetized Accretion Disks**

Kris Beckwith[1], J. B. Simon[1], P. J. Armitage[1]

[1]*JILA, UC Boulder.*
9:00 AM - 6:30 PM

It is now widely accepted that accretion onto black holes is driven by magnetohydrodynamic turbulence arising from the magnetorotational instability (MRI). This turbulence is often associated with fluctuations on timescales shorter than the orbital timescale and spatial correlations that are small compared to the disk scale height, consistent with expectations arising from a local picture of angular momentum transport. We present results from recent high resolution simulations of magnetized accretion disks in the local, mesoscale and global limits that demonstrate that while magnetized accretion disk turbulence possesses a strong local component, correlations in the magnetic field on size scales much greater than the disk scale height emerge naturally from the turbulence itself. These correlations play an important role in angular momentum transport, disk variability and the formation of density fluctuations on large spatial scales within the disk. Careful study of the convergence properties of these long wavelength correlations from the local to mesoscale limits fails to reveal a spatial scale on which the magnetic field de-correlates, suggesting that angular momentum transport in magnetized accretion disks is a global, rather than local phenomenon.

247.05 – **H2O Megamasers: Measuring the Mass of the Black Hole in the AGN of Mrk1210**

Stephen Clouse[1], J. A. Braatz[2], C. Kuo[3]

[1]*Brigham Young University,* [2]*National Radio Astronomy Observatory,* [3]*University of Virginia.*
9:00 AM - 6:30 PM

We present a map of the water maser emission from the nucleus of the Seyfert 2 galaxy Mrk 1210, as observed with the Very Long Baseline Array. The map shows that the masers span ~ 6 mas (0.8 pc). We detect redshifted and blueshifted components offset by ~ 250 km/s but detect no masers directly at the systemic recession velocity of the galaxy. The spectral profile of the maser in Mrk 1210 is somewhat unlike the characteristic triple-peaked profiles of classic water megamasers in AGN accretion disks. However, our map shows that the masers are aligned roughly perpendicular to extended radio continuum

structures in the nucleus, suggesting the masers come from the accretion disk. We find that we can fit the maser distribution with a flat, inclined disk, with two of the maser loci falling near the midline of the disk and a third coming from an azimuthal angle of 47 degrees on the near side of the disk. We analyzed archival GBT spectra of this galaxy to measure line-of-sight accelerations of the maser lines, and we find them all to have accelerations less than .25 km/s/yr, which is consistent with the flat disk model. With this scenario, we can estimate the mass of the central black hole to be approximately 1.3×10^7 $M_\odot$.

This work was done as an REU project at the NRAO in Charlottesville, VA and was funded by the NSF.

247.06 – **Constraining Intermediate Mass Black Holes with Cosmological Microlensing**

Katherine J. Mack[1], L. A. Moustakas[2]

[1]*University of Cambridge, United Kingdom,* [2]*Jet Propulsion Laboratory.*
9:00 AM - 6:30 PM

We show how microlensing from line-of-sight galaxies in multiply imaged quasars can be used to constrain the mass fraction in massive compact objects. The statistics of microlensing events, which have been used to determine the mass fraction in smoothly distributed dark matter versus small compact objects, can also place limits on populations of intermediate-mass black holes. We show that this method can be used to derive a new constraint on massive primordial black holes and may also have implications for studies of black hole merger histories.

247.07 – **The Cluster of Blue Stars Surrounding the M31 Nuclear Black Hole**

Tod R. Lauer[1], R. Bender[2], J. Kormendy[3], P. Rosenfield[4], R. F. Green[5]

[1]*NOAO,* [2]*Universitats-Sternwarte Munchen, Germany,* [3]*University of Texas,* [4]*University of Washington,* [5]*Large Binocular Telescope Observatory.*
9:00 AM - 6:30 PM

We obtained U330 and B band images of the M31 nucleus using the High Resolution Camera of the Advanced Camera for Surveys on board the Hubble Space Telescope. The spatial resolution in the U330-band, 0.03″ FWHM, or 0.1 pc at M31, is sufficient to resolve the outskirts of the compact cluster (P3) of UV-bright stars surrounding the M31 black hole. The center of the cluster is marked by an extended source that is both brighter and redder than the other P3 sources; it is likely to be a blend of several bright stars. We hypothesize that it marks the location of the M31 black hole. Both stellar photometry and a surface brightness fluctuation analysis, show that the P3 stellar population is consistent with early-type main sequence stars formed in a ~ 100 − 200 Myr old starburst population. In contrast, evolutionary tracks of post early asymptotic giant-branch stars, associated with late-stage evolution of an old population, also traverse the U and U−B domain occupied by the P3 stars; but we argue that only a few stars might be accounted for that way. PEAGB evolution is very rapid, and there is no progenitor population of red giants associated with P3. The result that P3 comprises young stars is consistent with inferences from earlier HST observations of the integrated light of the cluster. Like the Milky Way, M31 harbors a black hole closely surrounded by apparently young stars.

247.08 – **Implications of the Observed Ultra-luminous X-ray Source Luminosity Function**

Douglas A. Swartz[1], A. F. Tennant[2], R. Soria[3], M. Yukita[4]

[1]*USRA/MSFC,* [2]*NASA/MSFC,* [3]*CIRA/Curtin University, Australia,* [4]*UA/Tuscaloosa.*
9:00 AM - 6:30 PM

We present the X-ray luminosity function and other properties of a complete sample of 127 nearby galaxies containing 107 ultraluminous X-ray (ULX) sources with 0.3-10.0 keV luminosities in excess of 1e39 erg/s. The luminosity function shows a break or cut-off at high luminosities that deviates from its pure power-law distribution at lower luminosities. The cut-off is at roughly the Eddington luminosity for a 70-150 solar mass accretor. We examine the effects on the observed luminosity function of sample biases, of small-number statistics (at the high luminosity end), and of measurement uncertainties. We consider the physical implications of the shape and normalization of the observed luminosity function. The sample selection criteria and the basic properties of the sample galaxies are also presented and the luminosity function is also compared and contrasted to results of other recent surveys.

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248 – Dark Matter & Dark Energy

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

248.01 – **The DECalS Software for the Dark Energy Survey Spectrophotometric Calibration System**

Jason Wise[1], J. P. Rheault[1], D. L. DePoy[1]

[1]*Texas A&M University Department of Physics and Astronomy.*
9:00 AM - 6:30 PM

DECalS is a fully automated remote control program for the Dark Energy Survey spectrophotometric calibration system (DECal). Expected to be used roughly once a

month to calibrate the Dark Energy Camera, DECalS provides a TCP/IP server with commands to give the user access to all aspects of the calibration. There is a separate "expert mode" used for installation and debugging purposes. Data gathered from the DECal system will track changes in the throughput of the compete optical path of the telescope system.

248.02 – **DECal: A Spectrophotometric Calibration System For DECam.**

Jean-Philippe Rheault[1], D. L. DePoy[1], J. L. Marshall[1], T. Prochaska[1], R. Allen[1], J. Wise[1], E. Martin[1]

[1]*Texas A&M University.*

9:00 AM - 6:30 PM

We present preliminary results for a spectrophotometric calibration system that is being implemented as part of the DES DECam project at the Blanco 4 meter at CTIO. Our calibration system uses a 2nm wide tunable source to measure the instrumental response function of the telescope from 300nm up to 1100nm. This calibration will be performed regularly to monitor any change in the transmission function. The system consists of a monochromator based tunable light source that provides illumination on a dome flat that is monitored by calibrated photodiodes and allow us to measure the throughput as a function of wavelength. Our system has an output power of 2 mW, equivalent to a flux of approximately 800 photons/s/pixel on DECam. Preliminary results of the measure of the throughput of the telescope will be presented.

248.03 – **aTmcam: A Simple Atmosphere Transmission Monitoring Camera For Sub 1% Photometric Precision**

Ting Li[1], D. L. DePoy[1], D. L. Burke[2], R. Kessler[3], J. P. Rheault[1], J. L. Marshall[1], D. W. Carona[1], S. Boada[1], T. Prochaska[1]

[1]*Texas A&M University,* [2]*SLAC,* [3]*University of Chicago.*

9:00 AM - 6:30 PM

Traditional color and airmass corrections can typically achieve ~1% photometric precision. A major limiting factor is the variability in atmospheric throughput, which changes on timescales of less than a night. We present preliminary results for a system to monitor the throughput of the atmosphere, which should enable photometric precision when coupled to more traditional techniques of less than 0.5%. The system, aTmCam, consists of a set of imagers each with a narrow-band filter that monitors the brightness of suitable standard stars. Each narrowband filter is selected to monitor a different aspect of the atmospheric transmission, including the amount of precipitable water, aerosol optical depth, etc. We present performance modeling results and comparison of narrowband photometric measurements with spectroscopic measurements of the atmosphere; we show that the narrowband imaging approach can predict the throughput of the atmosphere to better than ~10% across a broad wavelength range.

248.04 – **Design and Testing of DECam**

Marcelle Soares-Santos[1], Dark Energy Survey Collaboration

[1]*Fermi National Accelerator Laboratory.*

9:00 AM - 6:30 PM

The Dark Energy Survey (DES) is a next generation optical survey aimed at measuring the expansion history of the universe using weak gravitational lensing, galaxy cluster counts, baryon acoustic oscillations, and Type Ia supernovae. To perform the survey, the DES Collaboration is building the Dark Energy Camera (DECam), a 3 square degree, 570 Megapixel CCD camera mounted at the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory. DES will survey 5000 square degrees of the southern galactic cap in 5 filters (g, r, i, z, Y). DECam will be comprised of 74 250 micron thick fully depleted CCDs. Construction of DECam is nearing completion. In order to verify that the camera meets technical specifications for DES and to reduce the time required to commission the instrument, we have constructed a full sized telescope simulator and performed full system testing and integration prior to shipping. Our tests included a simulated DES observing run in which we have collected 4 nights worth of data. We report on the results of these tests performed for the DECam and its impact on the experiment's progress.

248.05 – **Cosmic Shear Measurement with the Dark Energy Survey**

Barnaby T. Rowe[1], DES

[1]*University College London, United Kingdom.*

9:00 AM - 6:30 PM

The Dark Energy Survey will observe 5000 square degrees of sky and obtain photometric redshifts and precise shapes for 300 million galaxies. This will enable us to measure the dark energy equation of state to a few per cent level accuracy from each of a range of cosmic probes: weak gravitational lensing, galaxy clustering, supernovae and cluster counts. In this poster I focus on the correlated weak lensing signal found in random patches of the sky, often termed cosmic shear. This effect will typically distort a circular galaxy into an ellipse with a major to minor axis ratio of around 1.05. To measure the dark energy equation of state to per cent level precision, these quantities must be must be measured to an accuracy better than 0.002.

However, this measurement must also be performed in the presence of atmospheric blurring and telescope effects, which cause additional distortions of major to minor axis ratio 1.01 or larger. I describe research in the Dark Energy Survey Weak Lensing Working Group to develop methods to take these effects into account, accurately uncover the cosmic shear, and thus measure the dark energy equation of state.

248.06 – **Weak Lensing Simulations and Precision Cosmology with the Dark Energy Survey**

Matthew Becker[1]

[1]*University of Chicago, DES Simulations Working Group.*

9:00 AM - 6:30 PM

Weak lensing measurements are an essential part of near- and long-term large-area sky surveys aimed at an array of scientific goals, like understanding Dark Energy, elucidating further the connection between galaxies and dark matter halos, constraining modifications to General Relativity, etc. The weak lensing community has undertaken extensive simulation efforts, both CCD image simulations and computations of the cosmological weak lensing signals from large-scale structure simulations, in order to address the variety of systematic errors which can adversely effect these measurements and their interpretation. The next logical step in this effort is the construction of mock galaxy catalogs with weak lensing shear signals self-consistently from large-scale structure simulations. While these weak lensing mock galaxy catalogs have easily been made for small patches of sky (~10 square degrees), upcoming large-area sky surveys will image thousands of square degrees or more. I will describe a new multiple-plane ray tracing code which is able to produce full-sky weak lensing deflection, convergence, and shear fields suitable for the construction of weak lensing mock galaxy catalogs for large-area sky surveys. I will also highlight the application of this code to the Dark Energy Survey simulation effort. These simulations will be vital to understanding systematic errors in current and future weak lensing measurements from large-area sky surveys and the Dark Energy Survey.

248.07 – **Developing Antennas for Measuring Dark Energy**

Stanchfield Sara[1], P. T. Timbie[1], L. Bezroukov[1], D. Marulli[1], J. Lewis[2]

[1]*UW Madison,* [2]*University of Colorado Boulder.*

9:00 AM - 6:30 PM

The Cylinder Radio Telescope (CRT) is a new instrument designed specifically for 21-cm intensity mapping and the study of dark energy through the detection of Baryon Acoustic Oscillations. The 21-cm emission line of neutral hydrogen can be used to map large-scale structure in the universe. Mapping the 21-cm line promises new insights into galaxy formation, dark matter distribution and the dark energy that dominates the universe. We report on the design, fabrication and testing of feed antennas for the CRT prototype.

248.08 – **Angular Momentum in Bose-Einstein Condensed CDM Halos**

Tanja Rindler-Daller[1], P. R. Shapiro[1]

[1]*The University of Texas at Austin.*

9:00 AM - 6:30 PM

Extensions of the standard model of particle physics predict very light bosons, ranging from about 10^{-5} eV for the QCD axion to 10^{-33} eV for ultra-light particles, which could be the cold dark matter (CDM) in the universe. If so, their phase-space density must be high enough to form a Bose-Einstein condensate (BEC). The fluid-like nature of BEC-CDM dynamics differs from that of standard collisionless CDM (sCDM), so observations of galactic haloes may distinguish them. sCDM has problems with galaxy observations on small scales, which BEC-CDM may overcome for a large range of particle mass m and self-interaction strength g. Here we study the largely-neglected effects of angular momentum. Spin parameters lambda ~ 0.05 are expected from tidal-torquing by large-scale structure, just as for sCDM. Since lab BECs develop quantum vortices if rotated rapidly enough, we ask if this angular momentum is sufficient to form vortices in BEC haloes, affecting their structure with potentially observable consequences. We study the equilibrium of self-gravitating, rotating BEC haloes which satisfy the Gross-Pitaevskii-Poisson equations, to calculate if and when vortices are energetically favoured. We find that vortices form as long as the particle self-interaction is strong enough, which includes a large part of the range of m and g of interest for BEC-CDM haloes.

This work is supported by NASA, NSF and the Texas Cosmology Center.

248.09 – **The Shapes and Alignments of Dark Matter Halos**

Michael Schneider[1], C. S. Frenk[2], S. Cole[2]

[1]*Lawrence Livermore Natl Lab,* [2]*Institute for Computational Cosmology, Durham University, United Kingdom.*

9:00 AM - 6:30 PM

We present measurements of the triaxial dark matter halo shapes and alignment correlation functions in the Millennium and Millennium-2 N-body simulations. We largely confirm previous results on the distributions of halo axis ratios as a function of halo mass, but we show that the median angle between halo major axes at different halo radii can vary by a factor of 2 between the Millennium-1 and 2 simulations because of the

different mass resolution. Thus error in the shape determinations from limited resolution is potentially degenerate with the misalignment of halo inner and outer shapes used to constrain BCG alignments in previous works. We also present fits to the 3-D halo-halo and halo-mass alignment correlation functions that are necessary ingredients to triaxial halo models for large-scale structure and models for galaxy intrinsic alignments as contaminants for cosmic shear surveys. We measure strong alignments between halos of all masses and the surrounding dark matter overdensities out to several tens of Megaparsecs, in agreement with observed shear-galaxy and cluster shape correlations. We use these measurements to forecast the contribution to the weak lensing signal around galaxy clusters from correlated mass along the line-of-sight. For prolate clusters with major axes aligned with the line-of-sight the fraction of the weak lensing signal from mass external to the cluster can be twice that predicted if the excess halo alignment correlation is assumed to be zero.

248.10 – **Pulsar-driven Jets and the Non-existence of Dark Energy And Matter**

John Middleditch[1]

[1]*LANL.*

9:00 AM - 6:30 PM

The bipolarity of Supernova 1987A and other SNe can be understood in terms of its very early light curve as observed from the CTIO 0.4-m telescope, as well as the IUE FES, and the slightly later speckle observations of the ``Mystery Spot'' by two groups. These observations and the resulting kinematic solution can be understood in terms of pulsar emission from polarization currents induced beyond the pulsar light cylinder by the periodically modulated electromagnetic field, which are thus modulated at up to many times the speed of light (supraluminally induced polarization currents -- SLIP). With plasma available at many times the light cylinder radius, as would be the case for a spinning neutron star formed at the center of its progenitor, pulsed emission is directed close to the rotation axis, eviscerating this progenitor remnant, and continuing for months to years, until very little circumpulsar material remains. There is no reason to suggest that this evisceration mechanism is not universally applicable to all SNe with gaseous remnants remaining, forcing SNe into a geometry consisting of two polar jets and an equatorial torus, of which the former almost never encapsulate 56-Ni positron annihilation gamma rays well, and the latter, in the case of Type Ia SNe, only for those with the largest mass in excess of that lost to core-collapse. A large fraction of Type Ia SNe will therefore lie considerably below the width-luminosity relation as observed, complicating their usefulness as standard candles in cosmological interpretation, and possibly accounting for their apparent anomalous dimming with distance. Pulsar-driven jets from the SNe of the first stars also allow star clusters to form without the need for Dark Matter. SLIP also accounts for GRBs, the Sco X-1 and SS 433 jets, LMXBs, and predicts that GRB afterglows are 100% pulsed at ~500/(1+z) Hz.

248.11 – **The General Antiparticle Spectrometer (GAPS) as a New Approach to Search Dark Matter**

Mayra Lopez-Thibodeux[1]

[1]*San Francisco State University.*

9:00 AM - 6:30 PM

The General Antiparticle Spectrometer is being designed to detect low-energy cosmic-ray antideuterons, which are believed to be the byproduct of the annihilation of neutralinos, the possible main component of cold dark matter. The antiparticle is expected to be stopped by solid Si(Li) trackers to form an exotic atom which will cascade down to ground level producing well-defined x-rays and annihilate into a signature pion star. The GAPS is expected to be launched from Antarctica in 2015 on a long duration flight at high altitude. A GAPS prototype (pGAPS) is now being integrated with a detector of six Si(Li) modules in three planes, and a cooling system to keep the modules at -35 degree Celsius in order to achieve a resolution of 3 keV for 60 keV x-ray. ISAS Li batteries will feed electrical power to the various parts of the pGAPS system. The preamp-Si(Li) tracker system is now being tested and work is being done to reach the desired resolution. The pGAPS will be launched prior to the final flight at stratospheric altitude to test the performance of the spectrometer.

This research project was done in the Space Science laboratory at the University of California, Berkeley with SROP (Summer Research Opportunity Program) funding.

248.12 – **A Spectrograph for BigBOSS**

Pierre-Henri CARTON[1], C. Bebek[2], S. Cazaux[1], A. Ealet[3], D. Eppelle[1], J. Kneib[4], P. Karst[3], M. levi[2], C. magneville[1], N. Palanque-Delabrouille[1], V. Ruhlmann-Kleider[1], D. Schlegel[2], C. Yeche[1]

[1]*C.E.A., France,* [2]*LBNL,* [3]*CPPM, France,* [4]*LAM, France.*

9:00 AM - 6:30 PM

The Big-Boss spectrographs assembly will take in charge the light from the fiber output to the detector, including the optics, gratings, mechanics and cryostats. The 5000 fibers are split in 10 bundles of 500 ones. Each of these channel feed one spectrograph. The full bandwidth from 0.36µm to 1.05µm is split in 3 bands. Each channel is composed with one collimator (doublet lenses), a VPH grating, and a 6 lenses camera. The 500 fiber spectrum are imaged onto a 4kx4k detector thanks to the F/2 camera. Each fiber core is imaged onto 4 pixels.

Each channel of the BigBOSS spectrograph will be equipped with a single-CCD camera, resulting in 30 cryostats in total for the instrument. Based on its experience of CCD cameras for projects like EROS and MegaCam, CEA/Saclay has designed small and autonomous cryogenic vessels which integrate cryo-cooling, CCD positioning and slow control interfacing capabilities. The use of a Linear Pulse Tube with its own control unit, both developed by Thales Cryogenics BV, will ensure versatility, reliability and operational flexibility. CCD's will be cooled down to 140K, with stability better than 1K. CCD's will be positioned within 15µm along the optical axis and 50µm in the XY Plan. Slow Control machines will be directly interfaced to an Ethernet network, which will allow them to be operated remotely.

The concept of spectrograph leads to a very robust concept without any mechanics (except the shutters). This 30 channels has a impressive compactness with its 3m3 volume. The development of such number of channel will drive to a quasi mass production philosophy.

248.13 – **COsmic Sky MAchine (COSMA) For The Dark Energy Survey**

Brandon Erickson[1], G. Evrard[1], M. Busha[2], M. Becker[3], R. Wechsler[4], A. Kravtsov[3]

[1]*University of Michigan,* [2]*University of Zurich,* [3]*University of Chicago,* [4]*Stanford University.*

9:00 AM - 6:30 PM

We describe efforts by the Simulation Working Group (SimWG) of the Dark Energy Survey (DES) to develop an efficient workflow environment for the production of wide-area synthetic galaxy catalogs that include self-consistent gravitational shear. The COsmic Sky MAchine (COSMA) environment transforms multiple 10^{10}-particle N-body simulations of nested volumes into multi-band, catalog-level descriptions of galaxies covering the full sky to high redshift. Such catalogs serve as truth tables for science pipeline validation, and DES Science teams require multiple realizations covering different cosmologies to support a Blind Cosmology Challenge process now getting underway. We outline our processing steps, including required empirical input, and present initial validation tests of a LCDM catalog at z~1. We sketch efforts underway to integrate our codes with NSF XSEDE workflow and gateway tools, with the aim to reduce production time for a single cosmology, including N-body simulation generation, from months to weeks. By creating an efficient, portable framework for generating science-grade, synthetic galaxy catalogs, we hope to lay the groundwork for support of future optical surveys, such as LSST, whose large data volumes demand sophisticated simulations to extract the best possible science.

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249 – The Rossi X-ray Timing Explorer: Taking the Pulse of the Universe

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

249.01 – **X-ray Spectral Variations of the Extremely Massive Colliding Wind Binaries Eta Carinae and WR 140**

Michael F. Corcoran[1], K. Hamaguchi[2], A. M. T. Pollock[3], C. M. P. Russell[4], A. F. J. Moffat[5], S. Owocki[4], B. Ishibashi[6], K. Davidson[7], J. M. Pittard[8], R. Parkin[9]

[1]*USRA,* [2]*UMBC,* [3]*ESA, United Kingdom,* [4]*U. Delaware,* [5]*U. Montreal, Canada,* [6]*U. Nagoya, Japan,* [7]*U. Minnesota,* [8]*Leeds, United Kingdom,* [9]*ANU, Australia.*

9:00 AM - 6:30 PM

The Rossi X-ray Timing Explorer has, for the first time, provided detailed measures of the X-ray spectral variations in the two most important, high mass, evolved, highly eccentric colliding wind binaries, Eta Carinae and WR 140 though multiple orbital cycles. We report on the breakthroughs RXTE has achieved for these two binaries in observations spanning 15 years.

249.02 – **Caught In The Act: Disc-jet Coupling In The 2009 Outburst Of The Black Hole Candidate H1743-322**

Gregory R. Sivakoff[1], J. C. A. Miller-Jones[2], D. Altamirano[3], M. Coriat[4], S. Corbel[4], V. Dhawan[5], H. A. Krimm[6], R. A. Remillard[7], M. P. Rupen[5], D. M. Russell[3], R. P. Fender[8], S. Heinz[9], E. G. Koerding[10], D. Maitra[11], S. Markoff[3], S. Migliari[12], C. L. Sarazin[13], V. Tudose[14]

[1]*University of Alberta, Canada,* [2]*International Centre for Radio Astronomy Research - Curtin University, Australia,* [3]*University of Amsterdam, Netherlands,* [4]*CEA Saclay, France,* [5]*NRAO Domenici Science Operations Center,* [6]*NASA Goddard Space Flight Center,* [7]*MIT Kavli Institute for Astrophysics and Space Research,* [8]*University of Southampton, United Kingdom,* [9]*University of Wisconsin-*

Madison, [10]Radboud University Nijmegen, Netherlands, [11]University of Michigan, [12]Universitat de Barcelona, Spain, [13]University of Virginia, [14]Netherlands Institute for Radio Astronomy, Netherlands.
9:00 AM - 6:30 PM

We present an intensive radio and X-ray monitoring campaign on the 2009 outburst of the Galactic black hole candidate X-ray binary H1743-322. With the high angular resolution of the Very Long Baseline Array, we resolve the jet ejection event and measure the proper motions of the jet ejecta relative to the position of the compact core jets detected at the beginning of the outburst. This allows us to accurately couple the moment when the jet ejection event occurs with X-ray spectral and timing signatures. We find that X-ray timing signatures are the best diagnostic of the jet ejection event in this outburst, which occurs as the X-ray variability begins to decrease and the Type C quasi-periodic oscillations disappear from the X-ray power density spectrum. However, this sequence of events does not appear to be replicated in all black hole X-ray binary outbursts, even within an individual source. In our observations of H1743- 322, the ejection is contemporaneous with a quenching of the radio emission, prior to the start of the major radio flare. This contradicts the standard assumption that the onset of the radio flare marks the moment of ejection. The jet speed appears to vary between outbursts, with a possible positive correlation with outburst luminosity. The compact core radio jet reactivates on transition to the hard intermediate state at the end of the outburst, and not when the source reaches the low hard spectral state. Comparison with the known near-infrared behaviour of the compact jets suggests a gradual evolution of the compact jet power over a few days near the beginning and end of an outburst.

249.03 – **Marginally Stable Nuclear Burning**

Tod E. Strohmayer[1], D. Altamirano[2]
[1]NASA's GSFC, [2]Astronomical Institute, "Anton Pannekoek", Netherlands.
9:00 AM - 6:30 PM

Thermonuclear X-ray bursts result from unstable nuclear burning of the material accreted on neutron stars in some low mass X-ray binaries (LMXBs). Theory predicts that close to the boundary of stability oscillatory burning can occur. This marginally stable regime has so far been identified in only a small number of sources. We present Rossi X-ray Timing Explorer (RXTE) observations of the bursting, high-inclination LMXB 4U 1323-619 that reveal for the first time in this source the signature of marginally stable burning. The source was observed during two successive RXTE orbits for approximately 5 ksec beginning at 10:14:01 UTC on March 28, 2011. Significant mHz quasi-periodic oscillations (QPO) at a frequency of 8.1 mHz are detected for approximately 1600 s from the beginning of the observation until the occurrence of a thermonuclear X-ray burst at 10:42:22 UTC. The mHz oscillations are not detected following the X-ray burst. The average fractional rms amplitude of the mHz QPOs is 6.4% (3 - 20 keV), and the amplitude increases to about 8% below 10 keV.This phenomenology is strikingly similar to that seen in the LMXB 4U 1636-53. Indeed, the frequency of the mHz QPOs in 4U 1323-619 prior to the X-ray burst is very similar to the transition frequency between mHz QPO and bursts found in 4U 1636-53 by Altamirano et al. (2008). These results strongly suggest that the observed QPOs in 4U 1323-619 are, like those in 4U 1636-53, due to marginally stable nuclear burning. We also explore the dependence of the energy spectrum on the oscillation phase, and we place the present observations within the context of the spectral evolution of the accretion-powered flux from the source.

249.04 – **Long Term Monitoring Of PSR B0540-69 With RXTE**

Francis E. Marshall[1]
[1]NASA's GSFC.
9:00 AM - 6:30 PM

RXTE has monitored PSR B0540-69, the young, Crab-like pulsar in the LMC, since early January 1999 and maintained a phase-connected timing solution. We report on a search for glitches in phase or frequency, changes in the braking index, and a determination of the pulsar position.

249.05 – **The Neutron star Interior Composition ExploreR**

Zaven Arzoumanian[1], K. Gendreau[2], NICER Team
[1]NASA GSFC/CRESST/USRA, [2]NASA GSFC.
9:00 AM - 6:30 PM

The Neutron star Interior Composition ExploreR (NICER) will be a NASA Explorer Mission of Opportunity, currently in a Phase A study, dedicated to the study of neutron stars, the only places in the Universe where all four fundamental forces of Nature are simultaneously important. Answering the long-standing astrophysics question "How big is a neutron star?," NICER will confront nuclear physics theory with unique observational constraints, exploring the exotic states of matter within neutron stars and revealing their interior and surface compositions through rotation-resolved X-ray spectroscopy. Absolute time-referenced data will allow NICER to probe the extreme physical environments of the most powerful cosmic particle accelerators known. Finally, NICER will definitively measure the stabilities of pulsars as clocks, with implications for gravitational-wave detection, a pulsar-based timescale, and autonomous spacecraft navigation. NICER will fly on the International Space Station while Fermi is in orbit and post-RXTE, enabling the discovery of new high-energy pulsars and providing continuity in X-ray timing astrophysics.

249.06 – **The Large Observatory for X-ray Timing (LOFT): An ESA M-class Mission Concept**

Paul S. Ray[1], M. Feroci[2], J. den Herder[3], E. Bozzo[4], L. Stella[5], LOFT Collaboration
[1]NRL, [2]INAF/IASF-Roma, Italy, [3]SRON, Netherlands, [4]ISDC, Switzerland, [5]INAF/OAR, Italy.
9:00 AM - 6:30 PM

High-time-resolution X-ray observations of compact objects provide direct access to strong-field gravity, to the equation of state of ultradense matter and to black hole masses and spins. RXTE spectacularly demonstrated the promise of X-ray timing by revealing an extraordinary range of previously unknown variability phenomena from neutron stars and black holes. However, redeeming that promise and exploiting these phenomena to answer fundamental astrophysical questions will require a larger-area follow-on mission. Technological advances, such as large-area monolithic silicon drift detectors, have made it feasible to attain an order of magnitude or more increase in effective area that is still compatible with a medium class launch vehicle. LOFT is an ESA Cosmic Vision M-class mission concept that is undergoing an assessment phase study. It is one of 4 concepts in consideration for the M3 launch slot, estimated for 2022. The LOFT Large Area Detector (LAD) will achieve an effective area of 12 m^2 in the 2-30 keV band (compared to 0.6 m^2 for the RXTE PCA). A Wide Field Monitor (WFM) will provide context and triggering information, which is crucial for optimizing the observing plan of the LAD. We will describe the LOFT mission and instruments and present some options for NASA-funded US contributions that are currently under consideration.

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250 – White Dwarfs

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

250.01 – **R Coronae Borealis Stars As The Result Of White Dwarf Mergers?**

Jan E. Staff[1], A. Menon[2], F. Herwig[2], W. Even[3], G. Clayton[1], J. Tohline[1], C. L. Fryer[3], P. Motl[4], T. Geballe[5]
[1]Louisiana State University, [2]University of Victoria, Canada, [3]Los Alamos National Laboratory, [4]Indiana University Kokomo, [5]Gemini Observatory.
9:00 AM - 6:30 PM

R Coronae Borealis (RCB) stars have masses around a solar mass, are hydrogen-deficient variable stars that suddenly fade by several magnitudes at irregular intervals after which they gradually return to their original brightness over a period of some months. The fading is thought to be due to the formation of dust blocking light from the star. RCBs are often thought to be the result of the merger of a He and a CO white dwarfs. Here we present the results of 3 dimensional hydrodynamic simulations of the merger of double white dwarf systems where total mass is 0.9 solar mass and initial mass ratios ranging between q=0.5 and q=1. We use a zero-temperature plus ideal gas equation of state that allows for heating through shocks. These simulations allow us to follow the evolution of the system for 10-20 initial orbital periods (1000-2000 seconds) to a point after merger when the combined object has settled into a nearly steady-state like configuration. A hot shell forms around the merged core in low q simulations, but not in the high q simulations. The conditions found in the steady state like configuration is used as input to a nucleosynthesis code. We are particularly interested in seeing how much ^{18}O is formed, as observations of RCB stars often show a very high ratio of ^{18}O to ^{16}O of order unity. In the very best case scenario, we find a ratio of 1/12 in the hot shell.

This work has been supported, in part, by grant OIA-0963375 from the U.S. National Science Foundation and, in part, by NASA/ATP grants NNX10AC72G. This research also has been made possible by grants of high-performance computing time on the TeraGrid (TG-AST090104), at LSU, and across LONI (Louisiana Optical Network Initiative), especially awards loni_astro08 and loni_astro09).

250.02 – **HST Observations of WD1337+705: A New Determination of the Metal Accretion Rates**

Jean Dupuis[1], P. Chayer[2], V. Henault-Brunet[3]
[1]Canadian Space Agency, Canada, [2]Space Telescope Science Institute, [3]Institute of Astronomy, University of Edinburgh, United Kingdom.
9:00 AM - 6:30 PM

WD1337+705 (EGGR 102, G 238-44)) is a DAZ white dwarf. Previous optical and UV

observations have revealed high abundances of heavy elements in its atmosphere in spite of being in an effective temperature range where selective radiative acceleration of metals is not expected to be significant. Unlike many DAZ with high metal abundances, it does not exhibit a clear infrared excess that would normally indicate the presence of a dust disk around the star. In order to further our understanding of this star and related objects, we have acquired high resolution ultraviolet spectra of this star with the goal of characterizing the metallic content of its atmosphere through a detailed model atmosphere analysis of these spectra. Specifically, we focus on the analysis of the spectra recently obtained with the Cosmic Origin Spectrograph (COS) and STIS from which we report the detection of Al, Mg, and Fe. By combining these new measurements with time-dependent simulation of diffusion in presence of accretion, we put stringent constraints on the accretion rates for the different species detected and on the composition of the accreted matter.

250.03 – **Time-series UV Photometry Of Two Variable Carbon-atmosphere (DQV) White Dwarfs**

Kurtis A. Williams[1], M. H. Montgomery[2], D. E. Winget[2]

[1]*Texas A&M - Commerce,* [2]*UT Austin.*

9:00 AM - 6:30 PM

We present time-series near-UV photometry of two variable carbon-atmosphere (DQV) white dwarfs observed with GALEX. We compare the amplitudes, periods, and phases of these data with contemporaneous ground-based optical time-series photometry. These results help to shed light on DQVs, their properties, and the source of the variability. This research is funded by NASA-GALEX grant NNX11AG82G.

250.04 – **Deriving the Ages of the Oldest White Dwarfs: A Bayesian Analysis**

Erin M. O'Malley[1], T. von Hippel[2], M. Kilic[3]

[1]*Siena College,* [2]*Embry-Riddle Aeronautical University,* [3]*University of Oklahoma.*

9:00 AM - 6:30 PM

We present a Bayesian analysis of 130 SDSS cool white dwarfs with optical and infrared photometry, a subset of which also has trigonometric parallax measurements. Instead of a step-wise progression of fitting a temperature, mass, and age for each star (as is done in previous studies), we employ a Bayesian analysis to simultaneously and self-consistently fit model atmospheres, white dwarf evolutionary models, initial-final mass relation, and precursor main-sequence ages to derive posterior age distributions. We fully incorporate the non-Gaussian nature of stellar evolution in this analysis. The goal of our study is to mine the age information available in these and other cool white dwarfs in order to better understand the details of how the different models affect age determinations of white dwarfs.

250.05 – **SOAR + SMARTS Southern White Dwarf Survey**

John P. Subasavage[1], S. Lepine[2]

[1]*United States Naval Observatory - Flagstaff,* [2]*American Museum of Natural History.*

9:00 AM - 6:30 PM

We present early results from the SOAR + SMARTS Southern White Dwarf SURVEY (SSSWDS). Our initial sift of relatively bright ($15 < V < 18$), white dwarf candidates uses the technique of reduced proper motion with inputs from the SUPERBLINK proper motion database combined with photographic magnitudes. Crude distance estimates from the linear photographic magnitude-color relation of Oppenheimer et al. 2001 are obtained and permit prioritized follow-up. For confirmation of luminosity class, we use the SOAR telescope atop Cerro Pachon equipped with the Goodman Spectrograph and a moderate resolution grating. In tandem, we acquire multi-epoch, optical Johnson-Kron-Cousins BVRI photometry using the SMARTS 1.0m telescope atop CTIO. Combined with JHK from 2MASS, we compare the photometric SED to relevant white dwarf model atmospheres to estimate physical parameters (e.g., effective temperature, mass) and distance. For the nearest targets, specifically those within the RECONS (www.recons.org) horizon of 25 pc, we aim to obtain trigonometric parallaxes as part of the Cerro Tololo Inter-American Observatory Parallax Investigation (CTIOPI) project being conducted at the SMARTS 0.9m telescope.

To date, we have confirmed ~100 relatively bright, new white dwarfs in the southern hemisphere. Of those, 13 are estimated to be within our 25 pc horizon-of-interest, including two that are estimated to be within 15 pc. Ongoing observations will boost these figures by the end of the project.

250.06 – **Common Proper Motion Wide Double White Dwarfs Selected From the Sloan Digital Sky Survey**

Jeffrey Andrews[1], M. Agueros[1], K. Belczynski[2], S. Dhital[3], S. Kleinman[4], A. West[5]

[1]*Columbia University,* [2]*University of Warsaw, Poland,* [3]*Vanderbilt University,* [4]*Gemini Observatory,* [5]*Boston University.*

9:00 AM - 6:30 PM

Although they generally receive less attention, wide compact object binaries presumably outnumber their close cousins. Bolstered by our population synthesis results predicting the existence of white dwarf pairs (WDWDs) with up to parsec separations, we search for wide WDWDs using as our candidate primaries the ~12,000 spectroscopically confirmed hydrogen-atmosphere WDs recently identified in the Sloan Digital Sky Survey. Our method is adapted from that of Dhital et al. and identifies candidate common proper motion WDWDs at angular separations of up to 10'. We use a Monte Carlo Galactic model to determine each candidate binary's false positive probability and uncover a significant number of new candidate wide WDWDs pairs. These pairs can serve as a probe of the cumulative effect of perturbations from distant stars in the Galactic disk and of the differential pull of the Galactic tidal potential. Spectroscopic follow-up will allow us to examine the radial velocities of these candidate binaries, as well as constrain WD cooling curves and the initial-final mass ratio for WDs.

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251 – CAE/CATS Astronomy Education Research

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

251.01 – **The Center for Astronomy Education (CAE) Collaboration of Astronomy Teaching Scholars (CATS) Program: A Year-Four Research Update**

Gina Brissenden[1], C. Impey[2], E. E. Prather[1], K. M. Lee[3], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona,* [2]*Steward Observatory, Univ. of Arizona,* [3]*Univ. of Nebraska.*

9:00 AM - 6:30 PM

The Center for Astronomy Education (CAE) has been devoted to improving teaching & learning in Astro 101 by creating research-validated curriculum & assessment instruments for use in Astro 101 & by providing Astro 101 instructors professional development opportunities to increase their pedagogical content knowledge & instructional skills at implementing these curricula & assessment materials. To create sustainability and further expand this work, CAE, in collaboration with other national leaders in astronomy education & research, developed the Collaboration of Astronomy Teaching Scholars (CATS) Program. The primary goals of CATS are to: 1) increase the number of Astro 101 instructors conducting fundamental research in astronomy education; 2) increase the amount of research-validated curriculum and assessment instruments available for use in Astro 101; and 3) increase the number of people prepared to develop and conduct their own CAE Teaching Excellence Workshops. Our year-four research updates include an analysis of the LSCI using multiple psychometrics, results from teaching “mega-courses,” learning gains related to Citizen Science, common conceptual and reasoning difficulties related to cosmology, new resources available for instructors, a further look into science literacy, and many more. 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.

251.02 – **What does it take to create an effective and interactive learning environment with 700 students in a college Gen. Ed. Astro Course?**

Edward E. Prather[1], G. Brissenden[1], S. Cormier[1], J. Eckenrode[1], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona.*

9:00 AM - 6:30 PM

College-level general education (gen ed.) curricula in the US have many goals: exposing students to the breadth of human ideas; elevating their reading comprehension, writing abilities, critical reasoning skills; and providing an understanding of, and appreciation for, subjects outside of their chosen field of study. Unfortunately the majority of the teaching and learning for gen ed. courses takes place in large enrollment courses. In the wake of the recent US financial crisis, many institutions of higher learning face extreme budget cuts, leading many faculty to teach in substantially larger classes with increasingly fewer resources. At the University of Arizona this issue manifests itself in mega-classes with enrollments from 700-1400. We discuss key programmatic and pedagogical changes involved in successfully implementing proven collaborative learning strategies into an Astro 101 mega-class. From devising new ways to hand out and collect papers, to altering course seating, to outlawing cell phones and laptops, to implementing new ways of administering tests. We take a “what ever it takes” approach to engineering this mega-course environment so it can succeed as a learner-centered classroom. Paramount to the success of this course has been the creation of the new CAE Ambassadors program which advances the leadership role of prior non-science majors along the continuum from student, to teaching assistant, to science education researcher, to STEM minor.

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.

251.03 – **Final Results from a Large-Scale National Study of General Education Astronomy Students' Learning Difficulties with Cosmology**

Colin Scott Wallace[1], E. E. Prather[1], D. K. Duncan[2], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona,* [2]*Dept. of Astrophysical & Planetary Sciences, Univ. of Colorado at Boulder.*
9:00 AM - 6:30 PM

We recently completed a large-scale, systematic study of general education introductory astronomy students' conceptual and reasoning difficulties related to cosmology. As part of this study, we analyzed a total of 4359 surveys (pre- and post-instruction) containing students' responses to questions about the Big Bang, the evolution and expansion of the universe, using Hubble plots to reason about the age and expansion rate of the universe, and using galaxy rotation curves to infer the presence of dark matter. We also designed, piloted, and validated a new suite of five cosmology Lecture-Tutorials. We found that students who use the new Lecture-Tutorials can achieve larger learning gains than their peers who did not. This material is based in part upon work supported by the National Science Foundation under Grant Nos. 0833364 and 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.

251.04 – **Using Item Response Theory to Evaluate LSCI Learning Gains**

Wayne M. Schlingman[1], E. E. Prather[1], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona.*
9:00 AM - 6:30 PM

Analyzing the data from the recent national study using the Light and Spectroscopy Concept Inventory (LSCI), this project uses Item Response Theory (IRT) to investigate the learning gains of students as measured by the LSCI. IRT provides a theoretical model to generate parameters accounting for students' abilities. We use IRT to measure changes in students' abilities to reason about light from pre- to post-instruction. Changes in students' abilities are compared by classroom to better understand the learning that is taking place in classrooms across the country. We compare the average change in ability for each classroom to the Interactivity Assessment Score (IAS) to provide further insight into the prior results presented from this data set. This material is based 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.

251.05 – **Conceptual Surveys for Zooniverse Citizen Science Projects**

Sebastien Cormier[1], E. E. Prather[1], G. Brissenden[1], C. Lintott[2], P. L. Gay[3], J. Raddick[4], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona,* [2]*Adler Planetarium & University of Oxford, United Kingdom,* [3]*The Center for Science, Technology, Engineering and Mathematics Research, Education and Outreach at Southern Illinois University Edwardsville,* [4]*Johns Hopkins Univ.*
9:00 AM - 6:30 PM

The Citizen Science projects developed by Zooniverse allow volunteers to contribute to scientific research in a meaningful way by working with actual scientific data. In the Moon Zoo Citizen Science project volunteers classify geomorphological features in images from NASA's Lunar Reconnaissance Orbiter, and in the Galaxy Zoo project volunteers classify galaxies from SDSS-III and Hubble images. We created two surveys, the Lunar Cratering Concept Inventory (LCCI), and the Zooniverse Astronomy Concept Inventory (ZACS) to measure the impact that participation in Moon Zoo has on user conceptual knowledge. We describe how the survey was developed and validated in collaboration with education researchers and astronomers. The instrument was administered to measure changes to user conceptual knowledge as they gain experience with Moon Zoo. We discuss preliminary data analysis and how these results were used to change implementation of the survey to improve results. 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.

251.06 – **A Long-Term Study of Science Literacy and Attitudes Towards Science: Comparing Survey Responses of Undergraduates to Scientists**

Sanlyn Buxner[1], C. Impey[2], K. Tijerino[1], J. Antonellis[3], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Univ. of Arizona,* [2]*Steward Observatory, Univ. of Arizona,* [3]*Little Priest Tribal College.*
9:00 AM - 6:30 PM

Drawing from a database of over 10,000 undergraduate student responses to a science literacy survey, derived from policy driven projects (e.g. NSF Science Indicators), we have explored the change in students' understandings and beliefs about science and technology from 1989 to 2011. Our analysis has revealed little change in students' science literacy scores over twenty-two years. In addition, student demographic variables, including major and number of science courses completed, predicts less than 10% of the variance in students' overall science literacy scores. Recently, we have analyzed students' responses to four open-ended questions and compared their ideas to those of scientists asked the same questions. A word count analysis showed that when describing what it means to study something scientifically, students used the words "hypothesis", "study", "method", "test", and "experiment" the most. Surprisingly, scientists used the same words the most when answering the same question on a similar survey. In contrast, other words that scientists considered to be important in describing how to study something scientifically such as "creativity" and "imagination" were mentioned by only eleven students across the twenty-two years. Overall, there is evidence that non-science major students are able to describe science using many of the words we consider to be important in science although not in the same way as scientists. We describe implications of assessing student science literacy and learning what our students know about specific topics in science. 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.

251.07 – **Lecture-Tutorial Coherency: Student-Supplied Written-Responses As Indicators Of Future Success**

Jeff Eckenrode[1], J. D. Welch[1], H. Saldivar[2], J. Laird[1], E. E. Prather[1], S. Cormier[1], C. S. Wallace[1], G. Brissenden[1], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona,* [2]*CalPoly Pomona.*
9:00 AM - 6:30 PM

The Lecture-Tutorial Coherency Project investigates the importance of correctness and coherency in Lecture-Tutorial (LT) responses and their role in students' understanding of introductory astronomy content. Astronomy education researchers, including students from the Ambassador Program (former Astro 101 students who later became instructional assistants for Astro 101), designed rubrics geared towards assessing the correctness and coherency of student-supplied written-responses for specific LT questions. We used these rubrics to score the LT responses of over 1300 students. We then looked for a correlation between a student's ability to connect novel pieces of reasoning together to form a coherent argument in their LT and their performance on exam questions with closely aligned content. We will present results from our study. 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.

251.08 – **Animated Ranking Tasks: Student Attitudes, Practices, & Learning Gains**

Kevin M. Lee[1], E. E. Prather[2], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Univ. of Nebraska,* [2]*Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona.*
9:00 AM - 6:30 PM

A ranking task typically provides the learner with a series of pictures or diagrams that describe several slightly different variations of a basic physical situation. The student is then asked to make a comparative judgment and order or rank the various situations based on some physical outcome or result. These novel and intellectually challenging tasks effectively probe student understanding at a deep conceptual level.

For several years we have been developing a library of computer-based ranking and sorting tasks for introductory astronomy. The students in this study completed a series of animated ranking tasks on lunar phases, were surveyed regarding their experiences, and completed a pre/post assessment based on Lunar Phase Concept Inventory questions. The tasks communicated with a database and all student interactions were recorded. This poster will detail student learning gains, practices, and attitudes from the study. Interesting correlations between variables will be identified.

All eduational tools described in this poster are publicly available at http://astro.unl.edu. This material is based upon work supported by the National Science Foundation under Grants Nos. 0737376 and 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.

251.09 – **Teach Astronomy: An Online Resource for General Education and Informal Learning**

Kevin Hardegree-Ullman[1], C. Impey[1], A. Patikkal[2], A. Srinathan[2], Collaboration of Astronomy Teaching Scholars (CATS)

[1]*Steward Observatory, Univ. of Arizona,* [2]*Univ. of Arizona.*
9:00 AM - 6:30 PM

Teach Astronomy is a website developed for students and informal learners who would like to learn more general astronomy knowledge. This learning tool aggregates content from a myriad of sources, including: an introductory astronomy text book by C. D. Impey and W. K. Hartmann, astronomy related articles on Wikipedia, images from the Astronomy Picture of the Day, two to three minute video clips by C. D. Impey, podcasts from 365 Days of Astronomy, and news from Science Daily. In addition, Teach Astronomy utilizes a novel technology to cluster and display search results called a Wikimap. We present an overview of the website's features and suggestions for making the best use of Teach Astronomy in the classroom or at home. 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.

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252 – The Milky Way, The Galactic Center

Poster Session – Exhibit Hall – Tuesday, January 10, 2012, 9:00 AM - 6:30 PM

252.01 – **New Orbital Analysis of Stars at the Galactic Center Using Speckle Holography**

Anna Boehle[1], A. Ghez[1], R. Schoedel[2], S. Yelda[1], L. Meyer[1]

[1]*UCLA,* [2]*Instituto de Astrofisica de Andalucia (CSIC), Spain.*
9:00 AM - 6:30 PM

Since 1995 our group has monitored the stars orbiting the supermassive black hole, Sgr A*, at the Galactic Center. In that time, we have taken both speckle (1995-2005) and Adaptive Optics data (2005-present) and use the combined data sets to analyze the motions of stars orbiting Sgr A* and constrain its mass and the distance to the Galactic Center. The speckle data taken from 1995-2005 are very important in this orbital analysis due to their 10-year baseline. Originally, this data was analyzed using the speckle shift-and-add method. Here we present the results of an improved analysis of this data using a technique called speckle holography. With this new analysis, we have increased the depth of our 1995-2005 maps by 2 magnitudes when compared to the shift-and-add maps. We thus add a 10-year baseline for stars that were previously only seen in the AO epochs and are able to better constrain their orbital parameters.

252.02 – **Probing The Kinematics Of Ionized Gas In The Galactic Center**

Marc Royster[1], F. Yusef-Zadeh[1], J. Braatz[2]

[1]*Northwestern University,* [2]*National Radio Astronomy Observatory.*
9:00 AM - 6:30 PM

We have carried out radio recombination line (RRL) observations of the inner 2.0x0.5 (lxb) degrees of the Galactic center using the 100 m Green Bank Telescope. These measurements provided 0.9 km/s spectral resolution, 73" spatial resolution, and was sensitive to six RRLs (H86alpha - H91alpha) with the center transition at 9.17 GHz. An on-the-fly frequency-switched Nyquist sampled mapping scheme centered at l=359.95, b=-0.0473 was utilized. Here, we present preliminary results of this extensive survey of ionized gas with maps of the integrated intensity and details of various kinematical features. In particular, the kinematics of the diffuse Warm Ionized Medium as well as well-known massive star forming sites such as: Sgr A, Sgr B1 (G0.5-0.0), Sgr B2 (G0.7-0.0), Sgr C (G359.4-0.1), the sickle (G0.18-0.04), and the arched filaments of the radio arc near l~0.18 degrees are given. Highlights of this survey include the detection for the first time of various diffuse emission throughout the Galactic center. One such feature is an extensive large scale blueshifted structure from -80 to 0 km/s that appears to extend from Sgr C to the western ridge of the thermal arch at G0.07+0.04, a projected distance of ~75 pc (30'). In addition, we find an extended broad ionized thermal component at ~0 km/s near G0.15-0.18. This large-scale ridge of ionized gas runs between the linear nonthermal filaments and the Sgr A complex, mirroring the thermal arched filaments. The morphology of this structure appears to trace a wind-blown cavity roughly 13.5 pc in extent at G0.14-0.12.

252.03 – **Analysis Of Submillimeter Mopra And Herschel Observations Of The Galactic Center**

Kirill Tchernyshyov[1], C. L. Martin[1], HIGGS Team

[1]*Oberlin College.*
9:00 AM - 6:30 PM

Observations of low-J transitions of CO, 13CO, CS, taken using the Mopra telescope, and of [CI], [CII], [NII], and high-J transitions of CO, taken with the HIFI instrument on Herschel, were used to model the behavior in Bania Clumps 1 and 2 in order to determine their contribution to hydrogen inflow to the galactic center. Modeling was done using Cloudy 10.00, as last described by Ferland et al. (1998). Relative line intensities were used to estimate hydrogen density and kinetic temperature in components of the clumps for fixed temperature and ultraviolet-irradiated conditions. While preparing the [CII] and [NII] data for modelling, an experimental HEB baseline removal technique based on matching reference spectra by first derivative was used.

252.04 – **Gravitationally Lensed X-Ray Sources at the Galactic Center**

Michael W. Castelaz[1], L. Rottler[1]

[1]*Pisgah Astronomical Research Inst..*
9:00 AM - 6:30 PM

More than two thousand x-ray sources located within 20 pc of the Galactic Center (GC) have been identified by Muno et al. (2003). If an x-ray source is located behind the Galactic Center and offset by a small angle from the GC projected on the sky, then that x-ray source could be gravitationally lensed. The consequences of finding gravitationally lensed sources at the Galactic Center include the ability to independently measure the mass of the GC as well as provide a new probe of the density distribution of the GC (e.g. Wardle & Yusef-Zadeh 1992). Inspecting x-ray images of the GC we were immediately drawn to a set of four x-ray objects. The identified objects are cataloged as CXOJ 174541.0-290014, 174540.1-290005, 174540.0-290031, and 174538.1-290022. These are the brightest and most obvious variable x-ray objects whose positions suggest patterns of images that may either be an inclined quad or two sets of dual gravitational lens patterns. Based on the image patterns, and image brightnesses and relative variations, we modeled possible lens systems using two algorithms. Both of the algorithms describing gravitational lenses are based on the Fermat potential and its time derivatives. For a lens radius of R = 0.01 pc, the total enclosed mass is 2.6 x 10^7 M⊙ and for R = 0.001 pc, the total enclosed mass is 2.6 x 10^5 M⊙. These masses are consistent with other measurements of the mass of the GC, such as 4.5 x 10^6 M⊙ (Ghez et al. 2008). We will present these results and our plans to further study the nature of these x-ray objects.

252.05 – **The Bulge Radial Velocity Assay (BRAVA): Final Results, A New High Velocity Star, and Public Data Release**

Robert Michael Rich[1], A. M. Kunder[2], R. de Propris[3], A. M. Koch[4], C. I. Johnson[1], C. D. Howard[1], S. A. Stubbs[2], J. Shen[5], Y. Wang[6], A. C. Robin[7], D. B. Reitzel[8], H. Zhao[9], P. Frinchaboy[10], L. Origlia[11], J. Kormendy[12]

[1]*UCLA,* [2]*CTIO,* [3]*European Southern Observatory, Chile,* [4]*landessternwarte Heidelberg, Germany,* [5]*Shanghai Astronomical Observatory, China,* [6]*Beijing Astronomical Observatory, China,* [7]*Observatoire Besancon, France,* [8]*Griffith Observatory,* [9]*St. Andrews University, United Kingdom,* [10]*Texas Chrisitan University,* [11]*INAF-Observatory Bologna, Italy,* [12]*University of Texas, Austin.*
9:00 AM - 6:30 PM

We present new radial velocity measurements from the Bulge Radial Velocity Assay (BRAVA), a large scale spectroscopic survey of M-type giants in the Galactic bulge/bar region. The sample of ~4500 new radial velocities, mostly in the region -10 < l < +10 deg and b ≈ −6 deg, more than doubles the existent published data set. The new data confirm the cylindrical rotation observed at −8 deg, and are an excellent fit to the Shen et al. (2010) N-body bar model. We also measure the strength of the TiO epsilon molecular band as a first step towards a metallicity ranking of the stellar sample, from which we confirm the presence of a vertical abundance gradient. We also publish our complete catalog of radial velocities, photometry, TiO-strengths, and spectra, which is available at the IRSA archive.

We also report a possible new high velocity star, the first found in this direction, with radial velocity 447 km/sec, and space velocity ~550 km/sec if its distance is 8kpc. The star is a moderately metal poor M giant in the Galactic bulge, and has apogalacticon at least 20 kpc from the nucleus.

252.06 – **Stellar Kinematics in the Bar of the Milky Way**

Connor McKeel[1], P. Frinchaboy[1]

[1]*Texas Christian University.*
9:00 AM - 6:30 PM

In 2005 the Galactic Legacy Mid-Plane Survey Extraordinaire (GLIMPSE) found the Milky Way to contain a long bar within its structure, the results of this survey were unclear though of the full size, structure, and dynamics of the bar. Studying the bar is difficult due to the large extinction in

the inner mid-plane of the Galaxy. Using the Two Micron All Sky Survey (2MASS) and GLIMPSE I & II a large number of evolved stars, bright in the infrared can be identified in the area of the long bar. To explore the kinematics of the long bar, spectra of candidate long bar stars have been obtained to measure radial velocities, to measure the extent and kinematics of the long bar. Here we present

results from our first set of stars at |b|~3 deg.

252.07 – **New Results For Hypervelocity Stars Using N-body Simulations**

Idan Ginsburg[1], A. Loeb[2], H. B. Perets[2], G. A. Wegner[1]

[1]Dartmouth College, [2]Harvard University.

9:00 AM - 6:30 PM

Hypervelocity stars (HVSs) have sufficient velocity to escape the gravitational pull of the Galaxy. They were theorized in 1988, and first discovered in 2005. Today, there are at least 16 confirmed HVSs. We know of three mechanisms that can produce HVSs. The most well studied mechanism is the production of HVSs via the disruption of a binary star system by a massive black hole (MBH); such as the one in the center of the Milky Way (Sgr A*). The second mechanism is the inspiral of an intermediate mass black hole. The third mechanism involves the interaction of stars with stellar black holes. We use direct N-body integration to study the orbits of thousands of different systems around a MBH of 4×10^6 $M_\odot$; similar to the mass of SgrA*. We describe the various outcomes of our simulations, including the production of hypervelocity binaries (HVBs) via the disruption of a triple system by the MBH. Such HVBs may be ejected at close orbits that lead to mass-exchange and the formation of hypervelocity blue stragglers (BSs). Similarly, a triple disruption can lead to the capture, by the MBH, of two or even three stars. A captured binary can sometimes evolve into a BS, and at other times the system will collide with low enough velocity that a merger will take place. We describe these new results in detail, as well as additional new developments. This work was supported in part by Dartmouth College and Harvard University funds.

252.08 – **What Is The Color Of The Milky Way?**

Timothy Licquia[1], J. A. Newman[1]

[1]University of Pittsburgh.

9:00 AM - 6:30 PM

For most galaxies with known redshift, the properties we can measure best are their color and luminosity, making these quantities vital for classifying galaxies from the local universe to high z. However, it is difficult to determine these same properties for the Milky Way, the galaxy we can study in the most detail, due to our location within it. Here, we employ a new approach which is immune to the effects of interstellar reddening. Using new infrared measurements of the Milky Way's star-formation rate and dynamical measurements of its stellar mass (along with their attendant uncertainties), we identify samples of galaxies in Sloan Digital Sky Survey data with matching properties, and evaluate the distribution of colors and luminosities of these analogs. Essentially, we make the Copernican assumption that the Milky Way is not unusual for a galaxy of its mass and star formation rate. This procedure tightly constrains the possible photometric properties of the Milky Way; we present results for both ugriz colors and absolute magnitudes, and explore the impact of potential systematic errors. We also present a gallery of images of galaxies whose properties should be similar to those of the Milky Way. Our results show that the Milky Way must be amongst the brightest, reddest star-forming spiral galaxies, with an overall color which is likely only slightly bluer than the bluest red sequence galaxies.

252.09 – **A New Model for the Galactic Magnetic Field and Its Implications**

Ronnie Jansson[1], G. Farrar[1]

[1]New York University.

9:00 AM - 6:30 PM

We use the WMAP7 Galactic Synchrotron Emission map and more than 40,000 extragalactic rotation measures to constrain the Galactic magnetic field (GMF), using a substantially more general functional form than has been used previously, now including an out-of-plane component (as suggested by observations of external galaxies) and random and striated-random fields (motivated by theoretical considerations), along with three different components of disk and halo fields. Consistent with our earlier analyses, the best-fit model has a thin disk field and an extended halo field. However with the new, more general field model, a substantial portion of the halo field is found to consist of striated magnetic fields, with a large out-of-plane component. We test different models of relativistic electron distributions, and self-consistently model their parameters. The new GMF model presented here provides a greatly improved fit to the RM and synchrotron observations. The new model predicts that an external viewer of the Milky Way would observe very similar magnetic 'X'-like structures to those seen in radio observations of edge-on Milky Way analogues, such as NGC 891. We discuss the implications of this GMF for ultrahigh energy cosmic ray deflections, composition and sources.

252.10 – **GALFA-HI: Dust/Gas Comparisons**

Susan Clark[1], K. Douglas[2]

[1]University of North Carolina at Chapel Hill, [2]Arecibo Observatory, Puerto Rico.

9:00 AM - 6:30 PM

The Galactic Arecibo L-Band Feed Array (GALFA) is mapping the Arecibo sky in 21-cm neutral hydrogen emission. Last summer, GALFA HI data and IRIS infrared data were used to analyze the dust-to-gas ratio across various regions of the sky, looking for trends across the galactic environment. Maps of infrared excess, or regions of the sky where the interstellar dust is not completely traced by atomic hydrogen, were created. As molecular hydrogen cannot be observed in emission, one motivation for this IR excess study was to help establish whether regions of IR excess can be used to trace cold, dense regions of the interstellar medium (ISM) where molecular hydrogen forms, and other molecular gas accrues. Such molecular clouds are the precursors to star formation. Several regions of interest, and one cloud in particular, known as MBM 53-55, stood out in the IR excess analysis. Spectral analysis of both HI and CO data in several regions of significant IR excess confirmed the presence of molecular gas in MBM 53-55, and provided confirmation that the method of IR excess analysis is a useful tool for predicting molecular gas in the diffuse ISM.

This work was funded by the NSF Arecibo Observatory REU Program.

252.11 – **GALFA-HI: A Targeted Search For Star Formation on the Far Side of the Milky Way**

Nicholas Stantzos[1], M. Gostisha[2], R. Benjamin[2], S. Gibson[3], B. Koo[4], K. A. Douglas[5], J. Kang[4], G. Park[4], J. E. G. Peek[6], E. J. Korpela[7], C. Heiles[8], J. H. Newton[3]

[1]Northern Arizona University, [2]University of Wisconsin-Whitewater, [3]Western Kentucky University, [4]Seoul National University, [5]Dominion Radio Astrophysics Observatory, [6]Columbia University, [7]Berkeley Space Astron. Lab., [8]Univ. California-Berkeley.

9:00 AM - 6:30 PM

The I-GALFA Survey provides a unique window on the spiral structure of the Milky Way as it contains three coherent 21 cm features that have been identified as spiral arms: the Perseus Arm, the Outer Arm, and the recently discovered Outer Scutum-Centaurus Arm. Moreover, all three of these arms lie beyond the solar circle (although the Perseus arm is thought to cross interior to the solar circle for l< 50 degrees), so this gas does not suffer the kinematic distance ambiguity encountered in the inner Galaxy. We use this data and the CO surveys compiled by Dame et al (2001) to target a search for distant star formation regions seen in the Spitzer Space Telescope/GLIMPSE and WISE mid-infrared all-sky surveys. We characterize the HI arms, and present the star formation regions that may be potentially associated with these three arms. Many of these objects will need spectroscopic follow-up, but some have been previously identified in the Green Bank Telescope HII Region Discovery Survey of Anderson et al (2011). The Inner Galaxy ALFA (I-GALFA) survey is part of the Galactic ALFA HI data set obtained with the Arecibo L-band Feed Array (ALFA) on the Arecibo 305m telescope. Arecibo Observatory is part of the National Astronomy and Ionosphere Center, operated sequentially by Cornell University and Stanford Research Institute under Cooperative Agreement with the U.S. National Science Foundation.

252.12 – **The Radial Velocity Experiment (RAVE): A Stellar Spectroscopic Survey for Exploring the Formation History of the Galaxy**

Matthias Steinmetz[1], RAVE collaboration

[1]Leibniz Institute for Astrophysics Potsdam (AIP), Germany.

9:00 AM - 6:30 PM

The Radial Velocity Experiment (RAVE) is an ambitious all-sky spectroscopic survey to measure radial velocities and stellar atmosphere parameters (temperature, surface gravity) and abundances of up to one 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. Since the operation of RAVE started in April 2003, more than 520 000 spectra have been taken in the Ca-triplet region (8410-8790 Å) for 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 2-3 kilometers per second. RAVE has meanwhile published three data releases containing radial velocities, stellar parameters and distance estimates, and a further catalogue containing individual elemantal abundances. Science applications of RAVE include the identification of substructure in the Milky Way and to derive constraints on the gravitational potential of our Galaxy.

252.13 – **The Chemical Abundances of New Extremely Metal-Poor Giants with [Fe/H] < −3.0**

Jaehyon Rhee[1], M. Fink[2], W. Rhee[3]

[1]Gemini Observatory & Purdue University, [2]Purdue University, [3]West Lafayette High School.

9:00 AM - 6:30 PM

Extremely metal-poor (EMP) stars with [Fe/H] < −3.0 observable in the Galactic halo and thick disk today are believed to be the second-generation stars born out of those

materials that were slightly chemically polluted by the extinct, metal-free first stars. If true, these oldest surviving stars with the lowest metal abundances are astrophysical laboratories that may shed essential light on the origins and evolution of the chemical elements and on the formation of the Milky Way.

In order to newly discover field metal-deficient stars in the inner halo of the Galaxy, the Purdue Ultra Metal-Poor Star Survey (PUMPSS) program was conducted. Candidate metal-poor stars were initially selected utilizing the photometric data of the GALEX and the 2MASS, and subsequent medium- and high-resolution spectroscopy were carried out for the identification of true metal-poor giant stars and detailed chemical abundance analyses, respectively. We present an overview of the PUMPSS program and the results of the abundance analysis for high-dispersion spectra of EMP giant stars taken at the KPNO 4m telescope.

We acknowledge support for this work from NASA grants 07-ADP07-0080 and 05-GALEX05-27.

252.14 – **The Outer Halo Metallicity Distribution**

ZHIBO MA[1], H. Morrison[1], P. Harding[1], X. Xue[2], H. Rix[3], C. Rockosi[4], J. Johnson[5], Y. Lee[6], K. Cudworth[7]

[1]Department of Astronomy, Case Western Reserve University, [2]Key Lab of Optical Astronomy, National Astronomical Observatories, China, [3]Max Planck Institute for Astronomy, Germany, [4]UCO/Lick Observatory, UC Santa Cruz, [5]Department of Astronomy, Ohio State University, [6]Department of Physics & Astronomy, Center for the Study of Cosmic Evolution, and Joint Institute for Nuclear Astrophysics, Michigan State University, [7]Yerkes Observatory, The University of Chicago.
9:00 AM - 6:30 PM

We present a new determination of the metallicity distribution function in the Milky Way halo, based on an in situ sample of more than 5000 K giants from SDSS/SEGUE. We have also measured the metallicity gradient in the halo, using our sample which stretches from 5 kpc to more than 100 kpc from the galactic center. The halo metallicity gradient has been a controversial topic in recent studies, but our in-situ study overcomes the problems caused in these studies by their extrapolations from local samples to the distant halo. We also describe our extensive checks of the log g and [Fe/H] measurements from the SEGUE Stellar Parameters pipeline, using globular and open cluster stars and SEGUE stars with follow-up high-resolution analysis. In addition, we present a new Bayesian estimate of distances to the K giants, which avoids the distance bias introduced by the red giant branch luminosity function.

252.15 – **On Rings and Streams in the Galactic Anticenter**

Jeffrey L. Carlin[1], J. Li[2], H. J. Newberg[1], L. Deng[2], M. Newby[1], Y. Xu[2]

[1]Rensselaer Polytechnic Institute, [2]National Astronomical Observatories, Chinese Academy of Sciences, China.
9:00 AM - 6:30 PM

A number of low-latitude stellar overdensities have been found near the Milky Way anticenter at a Galactocentric distance of ~18-20 kpc. Our study combines SDSS photometry and spectroscopy from 34 regions containing SEGUE plates at latitudes b<40 degrees over the entire 145<l<235 degree span of the SDSS footprint to disentangle what appear to be three separate structures in this region. All three of these substructures have main sequence turnoff colors bluer than the thick disk, and appear as discontinuities in color-magnitude diagrams at magnitudes corresponding to a ~10 kpc distance from the Sun. We select spectra of likely substructure members from within the bluest color range of the turnoff (0.2<g-r<0.3) and between magnitudes 19<g<20. The mean radial velocity of the higher-latitude feature is distinct from the thick disk in this region, has a velocity dispersion of ~15 km/s, and a mean metallicity of [Fe/H]=-1.0. This feature extends from (l,b)~(220,23) to (160,37) degrees at relatively low surface brightness, with a sharp cutoff at its high-latitude edge. The other large substructure is present at all b<22-degree latitudes probed as a discrete feature ~18-20 kpc from the Galactic center. This feature has thick disk-like mean velocity, but dispersion of ~16 km/s and mean [Fe/H]=-0.8. We show that both the dispersion and metallicity of this feature are lower than the thick disk ([Fe/H]=-0.5) at slightly smaller (14 kpc) distances. There appears to be a discontinuity in stellar density, scale height and stellar population between lower latitude substructure properties and the thick disk, though an association with the Galactic disks cannot be ruled out. The two higher latitude substructures (identified as the ACS and EBS by Grillmair 2006) are most likely tidal streams; they cannot be static disk structures. This project is funded by NSF grant AST-09-37523 and AST-10-09670, and NSFC grants 10973015 and 11061120454.

252.16 – **Kinematical Clues to the Origin of the Virgo Stellar Stream**

William Yam[1], J. L. Carlin[1], D. I. Casetti-Dinescu[2], B. A. Willett[1], H. Newberg[1], S. R. Majewski[3], T. M. Girard[2]

[1]Rensselaer Polytechnic Institute, [2]Yale University, [3]University of Virginia.
9:00 AM - 6:30 PM

Milky Way stellar substructure has been detected in the Virgo constellation (the so-called Virgo Stellar Stream, or VSS; and the possibly associated Virgo Overdensity) using a variety of different stellar tracers over a large (perhaps 100-1000 square degrees) area of sky, but the nature of the overdensities has yet to be determined. Fortuitously, one of Kapteyn's Selected Areas (SAs) making up our deep proper motion survey (Casetti-Dinescu et al. 2006) intersects this structure. Our data in this field, denoted SA 103, span 40x40 arcminutes centered at (RA, Dec) = (178.8, -0.6). We supplemented our proper motions with multifiber spectroscopy. VSS members are selected via kinematics (radial velocities and proper motions), as well as position on the CMD. Theoretical isochrones were fitted to the identified members in the CMD to obtain distance. We find 14 candidates with properties consistent with membership in the VSS (based in part on comparison to previous detections), and use the mean 3-D kinematics of these members to derive an orbit for the VSS debris. We show that Virgo debris is near the pericenter of a high-eccentricity, plunging orbit similar to that found by Casetti-Dinescu et al. (2009) based on one VSS RR-Lyrae star. We explore possible progenitors for the VSS by integrating an orbit with the measured kinematics and comparing this to known Milky Way satellites and stellar substructures. At least three structures (a dwarf galaxy, globular cluster, and at least one diffuse stellar overdensity) are identified whose properties suggest that they may be related to the VSS. An n-body simulation of a Sagittarius-sized dwarf galaxy on our derived orbit produces a remnant with similar properties to the extant VSS detections, supporting the idea that the VSS is the remains of a tidally disrupted dwarf galaxy. Supported by NSF grants AST 09-37523, AST 11-15146, AST 10-09670.

252.17 – **Constraining the Mass of the Local Group through Proper Motion Measurements of Local Group Galaxies**

S. Tony Sohn[1], R. van der Marel[1], J. Anderson[1]

[1]STScI.
9:00 AM - 6:30 PM

The Local Group and its two dominant spiral galaxies have been the benchmark for testing many aspects of cosmological and galaxy formation theories. This includes, e.g., dark halo profiles and shapes, substructure and the "missing satellite" problem, and the minimum mass for galaxy formation. But despite the extensive work in all of these areas, our knowledge of the mass of the Milky Way and M31, and thus the total mass of the Local Group remains one of the most poorly established astronomical parameters (uncertain by a factor of ~4). One important reason for this problem is the lack of information in tangential motions of galaxies, which can be only obtained through proper motion measurements. In this study, we introduce our projects for measuring absolute proper motions of (1) the dwarf spheroidal galaxy Leo I, (2) M31, and (3) the 4 dwarf galaxies near the edge of the Local Group (Cetus, Leo A, Tucana, and Sag DIG). Results from these three independent measurements will provide important clues to the mass of the Milky Way, M31, and the Local Group as a whole, respectively. We also present our proper motion measurement technique that uses compact background galaxies as astrometric reference sources.

252.18 – **First Results From The C Field Of The ALFA ZOA Survey**

Alexandra Truebenbach[1], T. P. McIntyre[2], R. F. Minchin[3], P. A. Henning[2]

[1]Wesleyan University, [2]University of New Mexico, [3]Arecibo Observatory.
9:00 AM - 6:30 PM

The Milky Way causes extinction and confusion with about 20% of the optically visible extragalactic universe. The portion of the sky obscured by the Galactic Disk is known as the Zone of Avoidance (ZOA). Surveys of the sky at various wavelengths have helped to fill in the ZOA and understand the structure of the Universe behind the Milky Way. Using the Arecibo L-Band Feed Array (ALFA) a survey of the ZOA in neutral hydrogen (HI) is being completed that will further map the ZOA. We present preliminary results from the C field of the ALFA ZOA survey, covering 335 square degrees of the sky. Overall the preliminary C field catalogue contains 113 galaxy detections, including 58 previously unrecorded galaxies, and provides positions and HI parameters for all galaxies.

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201 – Dwarf Galaxies

Oral Session – Room 16B – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

201.02D – **Cold HI in Low Mass Galaxies**

Steven R. Warren[1], E. A. Petersen[2], E. D. Skillman[1], A. M. Stilp[3], J. Ott[4], J. J. Dalcanton[3], F. Walter[5], E. W. J. G. de Blok[6], B. Koribalski[7], A. A. West[8]

[1]University of Minnesota, [2]University of Illinois at Urbana-Champaign, [3]University of Washington, [4]NRAO, [5]Max Planck Institut fur Astronomie, Germany, [6]University of Cape Town, South Africa, [7]Australia Telescope National

Facility, Australia, [8]Boston University.
10:10 AM - 10:30 AM

Understanding star formation in low-metallicity systems is challenging due to the lack of detectable molecular gas (using CO as a tracer) in these environments. As star formation occurs primarily within molecular clouds, understanding how and where these clouds are most likely to form is an important piece of the star formation puzzle. Since the atomic hydrogen (HI) gas in star forming galaxies is the reservoir from which the molecular gas forms, cold HI is believed to be a necessary phase in converting the ubiquitous warm HI gas into cold molecular gas. Tracing the locations of cold HI gas via narrow HI line emission (e.g., Young et al. 1996, 1997) in low metallicity galaxies may currently be the best way to identify future sites of star formation. The uniformly high spectral (0.65 - 1.3 km/s) and spatial (~300 pc) resolution of the VLA-ANGST survey is ideally suited for identifying cold HI through line-of-sight narrow line emission. The VLA-ANGST sample consists of 36 nearby (<4 Mpc) low mass galaxies beyond the Local Group. We have detected cold HI in every galaxy observed with sufficient signal to noise (~20). The cold HI is typically near to, but not coincident with the peaks of the total HI emission. The cold HI also constitutes ~20-30% of the line flux, so it is never the dominant phase in the local interstellar medium.

201.03 – **WISE Discovery of Very Red Blue Compact Dwarf Galaxies**

Chao-Wei Tsai[1], R. Griffith[1], D. Stern[2], L. Yan[1], P. Eisenhardt[3], T. Jarrett[1], A. Blain[4], R. Assef[3], D. Benford[5], C. Bridge[6], J. Wu[3], Y. Wu[7], S. Petty[8], F. Masci[1], S. Stanford[9], E. Wright[8], J. Moustakas[10], B. Swift[11], F. Harrison[6], K. Madsen[6]

[1]IPAC, Caltech, [2]JPL/Caltech, [3]JPL, [4]Univ of Leicester, United Kingdom, [5]GSFC, [6]Caltech, [7]Mars and Co, [8]UCLA, [9]UC Davis, [10]UCSD, [11]Univ of Arizona.
10:30 AM - 10:40 AM

We present the results of a systematic search for mid-IR bright, low-metallicity blue compact dwarf galaxies (BCDs) using the WISE all-sky survey. WISE-selected BCDs have extremely hot dust, making them much redder than known optically-selected BCDs, and they have similar mid-infrared colors to obscured AGNs and red ULIRGs between 3.4 and 12 microns. Optical spectroscopic follow-up shows that the majority of WISE-selected BCDs have metallicities significantly lower than known BCD populations. Their > 100 Angstrom H-beta equivalent widths, similar to SBS 0335-052E, imply the existence of young (<5 Myr) star-forming regions. Despite their strong mid-infrared emission, WISE-selected BCDs show very low optical extinction, and thus provide a useful sample of transparent systems for detailed studies at optical through near-infrared wavelengths. These BCDs, showing recent star formation activity in extremely low metallicity environments, are likely low-redshift analogs to the first generation of galaxies to form in the universe.

201.04D – **Kinematics Of M31 dSphs And Implications For LCDM**

Erik J. Tollerud[1], R. L. Beaton[2], M. Geha[3], P. Guhathakurta[4], J. S. Bullock[1], J. S. Kalirai[5], E. N. Kirby[6], M. Boylan-Kolchin[1]

[1]University of California Irvine, [2]University of Virginia, [3]Yale University, [4]University of California Santa Cruz, [5]Space Telescope Science Institute, [6]California Institute of Technology.
10:40 AM - 11:00 AM

The Milky Way dwarf spheroidal (dSph) population are a unique testbed for both galaxy formation and LCDM. They represent the lowest-luminosity extreme of star formation and as a result harbor a number of interesting puzzles when placed in a cosmological context. However, interpretation of these satellites is compromised by the fact that they have only been characterized around the Milky Way. Hence, I present results from the SPLASH survey, a large spectroscopic survey of M31, focusing on searching the dSph satellites for signs of similar puzzles. These reveal consistency between the Milky Way and M31 satellite populations, showing these problems are not unique to the Milky Way. In particular, I highlight the "Massive Failures" problem, showing that, like the Milky Way dSphs, none of M31's satellites are consistent with being embedded inside the largest dark matter subhalos expected to reside inside a halo like that of M31. This likely presents either a critical challenge to LCDM or a breakdown of predictability in galaxy formation for the faintest known galaxies.

201.05D – **HI in Local Group Dwarf Galaxies: A Method of Discovery for Ultra-faint Dwarfs and a Probe of the Galactic Hot Halo**

Jana Grcevich[1]

[1]Columbia University.
11:00 AM - 11:20 AM

It is highly likely that additional ultra-faint dwarf galaxies exist in the Local Group but are outside the coverage region or too far away to be discovered in the SDSS data. The discovery of additional Local Group dwarfs is important to understand the discrepancies between Lambda CDM substructure on small scales and the observed Local Group dwarf population. Since HI containing Local Group dwarf galaxies are more likely to be located at distances greater than 270 kpc from the Milky Way or M31, searching for dwarfs via their HI provides a complementary method of discovery to optical searches. I present HI identified candidates for previously undiscovered Local Group dwarf galaxies which were selected from a catalog of compact, isolated neutral hydrogen clouds identified in the GALFA-HI survey. Clouds were selected based on how well their observational characteristics matched those of known Local Group dwarf galaxies (in particular the characteristics of the only known ultra-faint galaxy to contain HI, Leo T), as well as their kinematic characteristics. I will also present an analysis of SDSS data at the position of those dwarf galaxy candidates which are within the current SDSS coverage region. The gas content of previously known Local Group dwarfs can also be used as an indirect probe of the extended hot gas halo of the Milky Way and hot Local Group medium. I will discuss the constraints placed on the Milky Way's hot halo via ram pressure arguments, as well as presenting mass-loss rates from hydrodynamic simulations of gas stripping in low mass dwarf galaxies. This research was partially funded by NSF grants AST-0917810 and AST-0904059

201.06 – **The Small Magellanic Cloud: A Dwarf Irregular In Transition to a Dwarf Spheroidal**

Gurtina Besla[1]

[1]Columbia University.
11:20 AM - 11:30 AM

I will present new simulations of our nearest example of an interacting pair of dwarf galaxies, the Magellanic Clouds. Through detailed studies of their orbital evolution and large scale structure, insights can be gleaned into processes that affect the evolution of dwarf galaxies more generally. In particular, owing to a recent direct collision with the Large Magellanic Cloud, the Small Magellanic Cloud appears to be an object in the midst of a transition from a Dwarf Irregular galaxy to a Dwarf Spheroidal. Since dwarf-dwarf galaxy interactions are expected to be more frequent at higher redshift, this scenario might represent a more generic picture for the formation of Dwarf Spheroidals that is largely independent of interactions with massive spirals like the MW.

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202 – Evolution of Galaxies III

Oral Session – Room 19A – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

202.01 – **Comparison Of Galaxies At Redshifts Z~2 With Star-forming Clumps From HST CANDELS Observations To Those From Hydrodynamical Simulations**

Mark Mozena[1], S. M. Faber[1], D. C. Koo[1], J. R. Primack[1], A. Dekel[2], CANDELS Team

[1]University of California, Santa Cruz, [2]Racah Institute of Physics, The Hebrew University, Israel.
10:00 AM - 10:10 AM

Massive, star-forming clumps have been observed in z~2 galaxies. These clumps have been hypothesized to be a major contributor to the build-up of stellar mass during this epoch of high star formation and AGN activity. Using the deepest optical (ACS) and near infra-red (WFC3) observations from the HST Multi-Cycle Treasury CANDELS (Cosmic Assembly Near Infra-Red Deep Extragalactic Legacy Survey - candels.ucolick.org), we compare the properties of these clumps in the rest-frame near-UV and optical to those predicted by the latest cosmologically motivated hydrodynamical simulations (Hydro-ART by Ceverino, Dekel and Primack and Eris by Guedes and Madau). We render these simulated galaxy images to mimic the observed ACS and WFC3 images in CANDELS, and include the effects of dust obscuration, and use the observed simulations to explore measurable differences between in-falling clumps and those that have formed in the disk. We will present our latest results of comparing the observations of CANDELS galaxies with those from the latest hydrodynamical models that provide new and important insights into the nature and role of clumps in the mass assembly of galaxies in the z~2 universe.

202.02D – **Revealing the Assembly History of Disk Galaxies With The Tully-Fisher Relation to z~1.7**

Sarah Miller[1], R. S. Ellis[2], M. Sullivan[1], K. Bundy[3], T. Treu[4]

[1]University of Oxford, United Kingdom, [2]California Institute of Technology, [3]University of California Berkeley, [4]University of California Santa Barbara.
10:10 AM - 10:30 AM

We present new measures of the dynamics of disk galaxies and the Tully-Fisher relation to z~1.7, uncovering the nature of disk assembly over two-thirds the age of the universe. Using deep exposures from the DEIMOS and LRIS spectrographs on the Keck telescopes, as well as multi-band HST ACS imaging, we present modeled rotation curves for ~170 galaxies. Contrary to previous studies, we show that the stellar mass Tully-Fisher relation is tightly in place at z~1 with similar scatter to that found locally. Furthermore, we discuss evidence that there is no substantial change in this relation beyond z~1 to z~1.7. We explore the implications of a universe that largely obeys the

local stellar mass Tully-Fisher relation over two-thirds of its age.

202.03 – **Extremely Strong Emission-Line Galaxies In The WISP Survey And Implications For High-redhift Galaxies**

Hakim Atek[1], B. Siana[2], C. Scarlata[3], M. Malkan[4], P. McCarthy[5], H. Teplitz[6], A. Henry[7], J. Colbert[1]

[1]SSC - Caltech, [2]UC Riverside, [3]University of Minnesota, [4]UC Los Angeles, [5]Carnegie Observatories, [6]IPAC - Caltech, [7]UC Santa Barbara.
10:30 AM - 10:40 AM

The WFC3 Infrared Spectroscopic Parallel Survey (WISP) is a large (~ 700 orbits) HST program that uses WFC3 slitless spectroscopy to detect thousands of galaxies across a wide redshift range 0.3 < z < 2.3. We detect a population of extremely strong emission-line galaxies that undergoes very strong bursts of star formation. These dwarf galaxies have a higher specific star formation rate than normal star-forming galaxies at any redshift and tend to be extremely metal-poor. We show that in the absence of deep optical imaging, this population of high-EW galaxies is a source of contamination of high-z dropout galaxy samples. Finally, we empirically demonstrate that neglecting emission lines can dramatically affect the results of SED fitting of galaxies.

202.04 – **Early-type Galaxies At &Lt Z &Gt ~ 2 In Candels And Wisp Surveys**

Alejandro Bedregal[1], C. Scarlata[1]

[1]University of Minnesota.
10:40 AM - 10:50 AM

We present new results on the redshift evolution of the early type galaxy population from two large HST programs: the WFC3 Infrared Spectroscopic Parallel (WISP) survey and the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS). We simultaneously model the optical broad band photometry and near-infrared slitless spectroscopy from CANDELS and WISP fields to obtain spectrophotometric redshifts, stellar masses, ages, metallicities and structural parameters, for a large sample of z~2 passive galaxies. We explore different scaling relations (e.g. Mass-Size, Mass-Metallicity) and their evolution with redshift.

202.05D – **The Host Galaxies Of UV-selected AGNs At z~2-3**

Kevin Hainline[1], A. Shapley[1], J. Greene[2], C. Steidel[3]

[1]UCLA, [2]Princeton, [3]California Institute of Technology.
10:50 AM - 11:10 AM

An important goal for studies of galaxy formation consists of tracing a direct evolutionary connection between the growth of supermassive black holes powering active galactic nuclei (AGNs) and the build-up of stellar mass in their host galaxies. In the local universe, AGNs are preferentially found in bulge-dominated galaxies, but the AGN demographics at earlier epochs are not as well understood. We present a rest-frame UV composite spectrum for a sample of 33 z~2-3 AGNs drawn from the UV-selected Lyman Break Galaxy (LBG) survey. This spectrum shows many emission and absorption features, such as HI Lyman-alpha, NV 1240, NIV] 1483, 1486, CIV 1548, 1550, HeII 1640, and CIII] 1907, 1909. Redshifted SiIV 1394 absorption provides evidence for outflowing high-ionization gas in these objects at speeds of 10^3 km/s. Finally, using optical, near-IR, and mid-IR photometry, which cover the rest-frame UV to near-IR portions of the galaxies' spectral energy distributions, we perform stellar population synthesis modeling of the sample. Based on these results, we explore the relationship in the host galaxy between AGN activity, maturity of the stellar population, and regulation of star formation.

202.07 – **Extremely High Sfrs In Z~2 Galaxies: Multiwavelength Estimation Vs. Halpha Spectroscopy**

Peter Kurczynski[1], E. Gawiser[1], M. Huynh[2], R. J. Ivison[3], E. Treister[4], G. A. Blanc[5], E. Schinnerer[6], P. van der Werf[7], M. Urry[8], C. Cardamone[9], T. Greve[10], I. Smail[11], M. Swinbank[11]

[1]Rutgers, The State University of New Jersey, [2]University of Western Australia, Australia, [3]Royal Observatory, Edinburgh; UK ATC, United Kingdom, [4]Institute for Astronomy, University of Hawaii, [5]University of Texas, [6]Max Planck Institute for Astronomy, Germany, [7]Leiden University, Netherlands, [8]Yale University, [9]Massachusetts Institute of Technology, [10]Niels Bohr Institute Dark Cosmology Centre, Denmark, [11]Durham University, United Kingdom.
11:20 AM - 11:30 AM

It is generally accepted that SMG (Sub-Millimeter Galaxies) and BzKs (continuum color selected galaxies) have high Star Formation Rates (SFRs; e.g. 100-1000 Msun yr^{-1}); however, it is also the case that standard methods applied to some of these galaxies yield unbelievably high SFRs. We compare the SFRs of a sample of BzKs and SMGs with a variety of broadband methods, from radio through X-rays, to assess their consistency. We also study the SFRs of a select sub-sample of SMGs with AO/IFU spectroscopy in Halpha to understand the detailed origins of high SFR in these systems.

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203 – Supernovae II

Oral Session – Room 17B – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

203.01 – **The Extreme Hosts of Extreme Supernovae**

James D. Neill[1]

[1]California Institute of Technology.
10:00 AM - 10:10 AM

We present the results from a deeper survey of Luminous Supernova (LSN) hosts with the Galaxy Evolution Explorer (GALEX). We have added new, multiple kilo-second observations to our original observations of seventeen LSN hosts providing better constraints on their physical properties. We place the LSNe hosts on the galaxy NUV-r versus M(r) color magnitude diagram (CMD) with a larger comparison sample (~26,000) to illustrate the extreme nature of these galaxies. The LSN hosts favor low-density regions of the galaxy CMD falling on the blue edge of the blue cloud toward the low luminosity end. The new observations provide tighter constraints on the star formation rates (SFRs) and stellar masses, M(*), and show that the LSNe result from regions of high specific star formation and yet low total SFR. This regime is of particular interest for exploring the upper end of the stellar IMF and its variation. If our understanding of the progenitors of the LSNe leans toward very massive (> 200 M_sun) progenitors, the potential for a conflict with IMF theory exists because the conditions found in the hosts producing the LSNe should not create such massive stars. If it also required that LSNe can only be produced in primordial or very low metallicity environments, then they will also provide

evidence for strong variation in metallicity within a dwarf galaxy, since their masses are consistent with low, but not extreme metallicity.

203.02D – **Formation and Initial Evolution of Rayleigh-Taylor Clumps in the Ejecta of Supernova Simulations**

Carola I. Ellinger[1], P. A. Young[1], S. J. Desch[1], C. L. Fryer[2], G. Rockefeller[2]

[1]Arizona State University, [2]Los Alamos National Laboratory.
10:10 AM - 10:30 AM

Theoretical stability considerations and detailed numerical simulations have shown that Rayleigh-Taylor (RT) instabilities arise in a core-collapse supernova (SN) shortly after the explosion, leading to the early fragmentation of some regions in the ejecta. The clumps thus created are of interest to a variety of topics, for example delivery of material to the surrounding interstellar medium or comparison to SN remnant features like the Cassiopeia A ejecta knots. One particular interest to the authors in the former of those topics is delivery of SN material to forming planetary systems, our solar system in particular, since there is evidence that the solar system was contaminated with SN debris shortly before or during its birth. Knowledge of isotopic information and the full thermodynamic evolution of such overdense clumps is of interest to this topic, but only partially obtainable from observations. Thus it would be useful to be able to assess the physical properties of structures that form in the SN ejecta. Numerical simulations of the explosions of core collapse supernovae were done in 3 dimensions to study the formation of overdense clumps. The calculations were done with a particle- based hydrodynamics code and followed out to at least 0.5 yrs after the explosion. It is found that RT instabilities result in clumps in the He- and C+O rich regions in the exploding star that are overdense by 1-2 orders of magnitude and typically a few percent of the expanding ejecta size in diameter. These RT clumps are expected to be related to the ejecta knots of the type observed in the Cassiopeia A supernova remnant, probably evolving into them in the subsequent expansion. Further calculations to study the interaction of the expanding ejecta with appropriate surrounding media and to follow the further evolution of the RT clumps are underway.

203.03 – **The Rest Frame UV Properties of Type IIn Supernovae**

Peter Roming[1], T. Pritchard[2], S. Immler[3], P. Brown[4]

[1]Southwest Research Institute, [2]Penn State University, [3]Goddard Space Flight Center, [4]University of Utah.
10:30 AM - 10:40 AM

Unlike other classes of supernovae (SNe), Type IIn's are very bright in the UV and can be used in $z>2$ optical surveys (Cooke et al. 2009). Their intrinsic brightness and long-lived emission also aid in spectroscopically confirming these SNe in such surveys (Cooke 2008). Since they are associated with massive stars and because of their intrinsic UV brightness, Type IIn's are potentially strong probes of star formation out to relatively large redshifts ($z>2$). Here we present the UV properties of nearby Swift Ultra-Violet/Optical Telescope observed Type IIn SNe from early epochs. The data are then compared against rest frame UV observations of high-z counterparts in order to test for evolution.

203.04D – **Type Ia SNe Spectropolarimetry**

Paula Zelaya[1]

[1]*Pontificia Universidad Catolica De Chile, Chile.*
10:40 AM - 10:50 AM

We present optical spectropolarimetry of 7 Type Ia SNe taken with FORS2 at the Very Large Telescope of ESO Paranal Observatory. Our observations extend from pre-maximum to late phases,sampling the different types of asymmetries revealed as the photosphere recedes through deeper layers.

With this limited sample of SNe, already, we find that polarimetric characteristics of type Ia's are quite varied. We confirm that typical continuum polarization is low (~0.3 %), indicating low degree of global asymmetry. We also find that line polarization, related to local chemical, density, or excitation, asymmetries is fairly common, and shows a diverse behavior.

We present results on the SiII 6355 and CaII IR triplet features.

Line polarization in Si II, when present, shows a smooth evolution, increasing from early pre-maximum phases, peaking close to maximum light, and decreasing for couple of weeks after maximum, when it disappears. This behavior was known from the study of previous, smaller, samples. Our larger sample adds variety to the known evolution, suggesting to re-evaluate what we understand as typical.

Ca II IR triplet evolution is puzzling. Strong calcium line polarization is found at different phases of the light curve in many SNe, while some others show none. The line polarization does evolve with time, but, rather than decreasing after maximum, in many cases shoots up. When present, the feature is persistent. One SN shows it approximately two months after maximum.

We interpret the observations connecting the spectropolarimetric signals with the different stages of the explosion revealed at various SN phases. We emphasize the importance of enlarging the sample of SN observed in spectropolarimetry, extending the time of coverage, as well as increasing the time sampling near maximum.

P.Z. acknowledges support by Iniciativa Cientifica Milenio through the

Millennium Center for Supernova Science (NC10-064-F) and Conicyt (Beca de Doctorado)

203.05 – **Two Ultraluminous SNe at z~1.6 from the Supernova Legacy Survey**

Dale Andrew Howell[1], Supernova Legacy Survey

[1]*Las Cumbres Observatory / UC Santa Barbara.*
10:50 AM - 11:00 AM

We present griz lightcurves and spectra for two ultraluminous supernovae from the Supernova Legacy Survey (SNLS). SNLS-06D4eu, at a redshift of z=1.588 is one of the most luminous supernovae known, with M_U=-22.7, a luminosity of 3.4 x 10^{44} erg/s, and a total radiated energy of 10^{51} erg. It is also the highest redshift supernova with a spectrum. SNLS-07D2bv, at z~1.5 is similar. The four-filter, few-day cadence of the SNLS, and high redshifts provide the most in-dept look yet at the ultraviolet emission from these UV-bright events. These supernovae, 100 times brighter than a normal core-collapse supernova, are difficult to explain with current theory. We consider explanations involving radioactive decay, power via circumstellar interaction, and the creation and spin-down of a magnetar.

203.06D – **Multi-Wavelength Studies of SN Ia Host Galaxies**

Bradley E. Tucker[1], B. Schmidt[1], P. Garnavich[2]

[1]*Australian National University, Research School of Astronomy and Astrophysics, Australia,* [2]*University of Notre Dame.*
11:00 AM - 11:20 AM

Past investigations have shown a connection between the properties of SN Ia and their host galaxies. We refine these studies using UV through Mid-IR observations of both nearby and distant SN Ia hosts. These observations are based on ultraviolet (GALEX), optical (ESSENCE and CfA3/4), near-IR (PAIRITEL and 2MASS), and mid-IR (WISE) photometry along with optical spectra. We will present new results showing that the properties of SN Ia, both intrinsic and with respect to their use as distance indicators, appear to depend on a combination of metallicity, and star-formation rate of the host. We suggest that the stellar population age and location of the supernova progenitor can play a roll in using SN Ia as precision distance indicators, and advocate that a multi-wavelength approach is one way to disentangle the different influences.

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204 – Professional Ethics in Astronomy: An Ongoing Dialogue

Special Session – Ballroom E – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

The AAS recently endorsed a professional ethics statement, which along with the ethics guide for authors established by our journals, forms the framework for professional ethical behavior in the astronomical sciences.
Sigma Xi is using its 125th anniversary to devote the entire year of 2011 to ethics in the sciences, including education through the American Scientist magazine, activities across the country at professional meetings and regular articles in the American Scientist Magazine. I read the engaging column by Dr. Ahearne in the Jan/Feb issue entitled "Honesty" and felt that the time had come to again organize a panel session on professional ethics in astronomy at an AAS meeting. The last such panel session I organized was at the Minneapolis meeting in 2005, which, although scheduled in a small room, was a standing-room only event, with more than 150 people in attendance. Of particular importance to the people attending that session was the participation of the ApJ Editor-in-Chief, Robert Kennicutt and representatives from the funding agencies. Sigma Xi will produce a revised pamphlet on ethics during 2011 for general use and distribution.
The AAS provides new members with a copy of the National Academy of Sciences book "On Being a Scientist" (since 2006), which will be re-written this year with an eye toward changes in technologies used for communication, among other items. This is viewed favorably by our new members, especially Junior members and we plan to continue to distribute this low-cost volume in the future. The NAS has recently revised the edition, led in part by Rich Bissel, who serves as the Executive Director of NAS' office for Policy and Global Affairs.

204.01 – **Honesty in Professional Activities**

John F. Ahearne[1]

[1]*Sigma XI.*
10:00 AM - 10:15 AM

Honesty is an important subject in science and philosophy. Nobel Laureate Michael Bishop: “Each of us builds our discoveries on the work of others; if that work is false, our constructions fall like a house of cards and we must start all over again.” Sissela Bok has written on the pervasiveness and destructive power of lying. Not only is dishonesty corrosive to other’s efforts, it corrodes the dishonest person. In most professions, respect and trust by colleagues are critical in maintaining effective working relationships. Robert Fulghum described traits that should be learned in kindergarten. These include many that seem to be lacking in today’s political, economic, and communications realms.

204.02 – **Recent Studies of Research Ethics at the National Academy of Sciences**

Richard Bissell[1]

[1]*National Research Council.*
10:15 AM - 10:30 AM

Over the last few years, the National Academy of Sciences/National Research Council has been asked to revisit some of the core ethical issues for science that had not been properly explored since the 1990s. Some of the interest in this area related to the impact of technology changes in the sciences (e.g., management of massive data bases) and some to institutional changes (e.g., globalization of research teams, emergence of new scientific powers abroad, and new models in the publishing industry). As a result, a series of authoritative reports from the Academies’ Committee on Science, Engineering and Public Policy have been developed by expert committees and published - the third edition of *On Being A Scientist* (2009), a report on *Ensuring the Integrity, Accessibility, and Stewardship of Research Data in the Digital Age* (2009), and underway there is a new edition of *Responsible Science: Ensuring the Integrity of the Research Process* (first published in 1992, forthcoming in 2012). It is relevant in this age of global science that the latest edition of *OBAS* has been translated into multiple foreign languages, and the InterAcademy Council has launched its own project on research ethics with a report due from this multi-science academy body in the 2012-2013 period.

Some of the principal findings and issues raised in these reports will be presented by Richard E. Bissell, Executive Director for Policy and Global Affairs at the National Academy of Sciences.

204.03 – **Ethics for Proposal Review**

Linda S. Sparke[1]

[1]*NASA Headquarters.*
10:30 AM - 10:45 AM

When you ask for telescope time or research funding, you expect your proposal to be assessed fairly by impartial and knowledgeable reviewers. Ethical practices for peer review are aimed at making sure this happens. I will discuss confidentiality to protect both proposers and reviewers; conflicts of interest that might prevent a reviewer from being impartial; and how to give each proposal fair consideration. And for good peer review, we must all take our turns as a reviewer!

204.04 – **What is Plagiarism?**

Ethan T. Vishniac[1]

[1]*McMaster University, Canada.*
10:45 AM - 11:00 AM

Manuscripts submitted to The Astrophysical Journal are required to contain "novel and significant" material and to be free of plagiarism. There is a surprising amount of confusion regarding the definition of plagiarism and what constitutes prior publication. I will discuss the definitions used by the ApJ and the procedures we follow to to support this rule. Individual members of the community frequently show a very different understanding of these standards and are surprised at the conflict. Time allowing, I will briefly discuss some of the other common ethical problems that arise during the preparation and publication of articles.

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205 – How to Build a Milky Way: A Blueprint From the SDSS-III SEGUE Survey I

Special Session – Room 18C – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

As studies of the Milky Way enter the era of large surveys, we are finding that the new detailed, multi-dimensional datasets, combined with powerful new simulations of galaxy formation and evolution in a cosmological context, are transforming our view of the Milky Way's history. SEGUE is the SDSS project focused on the formation and evolution of the Milky Way as traced by its stars.

The survey observations are now complete, and the data have been released to the public. They consists of 3240 square degrees of ugriz imaging at low Galactic latitude and 370,000 stellar spectra to g=20. We have made extensive checks of our pipeline stellar parameter values using ugriz photometry and spectroscopy of well-studied cluster and field stars. The combination of large sample size and depth has enabled SEGUE to address long-standing questions such as the disk metallicity distribution and gradients, as well as newer questions such as the role of radial migration in shaping the disk. We have traced halo structure and substructure with larger and deeper samples than ever before, including thousands of outer halo giants. The homogeneous nature of the survey data also enable illuminating tests of selection biases, historically the bane of galactic stellar populations studies.

205.01 – **The SEGUE Survey: Overview Context**

Constance M. Rockosi[1]

[1]*University of California, Santa Cruz.*
10:00 AM - 10:12 AM

The SEGUE-1 and SEGUE-2 projects in SDSS-II and SDSS-III surveyed 400+ sparsely distributed 7 square degree pointings and 387,000 stars in the halo, anti-center and thick disk of the Milky Way. The publicly available data include the spectra, associated *ugriz* photometry and targeting information, radial velocity, and stellar parameter (metallicity, effective temperature, surface gravity) information. I will describe the survey data, how they were calibrated and how they can be accessed. I will review some additional, recent results from within and outside the collaboration to set the stage for the talks in the session.

205.02 – **The Metallicity Distribution Functions in Cool Stars in the SEGUE Survey**

Katharine Schlesinger[1]

[1]*University of California - Santa Cruz.*
10:15 AM - 10:27 AM

Using the G and K dwarfs from the SEGUE Survey, we determine the metallicity distributions of cool stars in the Milky Way disk with respect to R and |Z|, which provide important guidance for models of the formation and chemical evolution of the Milky Way thick disk. Benefiting from the well-defined and quantitative target selection algorithm of SEGUE, we weight our spectroscopic sample such that it accurately represents the underlying Milky Way populations. Although we cover a limited range in R, we detect a negative metallicity gradient for both spectral types below |Z| of 1 kpc. Above this height, our samples are consistent with a flat radial metallicity gradient. The two spectral types also show similar behavior to each other in the vertical direction, showing a consistent decrease in [Fe/H] with respect to increasing |Z|. Comparison with the thin and thick disk samples, defined by [α/Fe], from Lee et al. (2011) indicates that the vertical metallicity gradient reflects the transition in G and K dwarfs from a thin-disk-dominated sample at small |Z| to a sample consisting primarily of thick-disk stars at high |Z|. We compare our distributions to those of two different Galaxy models, from TRILEGAL (Girardi et al. 2004) and Schoenrich & Binney (2009a,b). Both models show little change in [Fe/H] with respect to |Z| and are unable to replicate the low-metallicity structure we observe. Therefore, our metallicity distribution functions challenge the assumptions that go into these models, which must be modified in light of the observations.

205.03 – **Abundance Trends in the Milky Way Disk as Observed by SEGUE**

Judy Cheng[1]

[1]*University of California Santa Cruz.*
10:30 AM - 10:42 AM

Detailed observations of the Galaxy can be used to test predictions made by models of disk formation and evolution, and they serve to complement large surveys that study galaxies at high redshift. The observed radial and vertical metallicity distribution of old stars in the Milky Way disk provides powerful constraints on the chemical enrichment and dynamical history of the disk. We present trends in [Fe/H] and [α/Fe] as a function of Galactocentric radius R and height above the plane |Z| using 7116 main sequence turnoff stars observed by the Sloan Extension for Galactic Understanding and Exploration (SEGUE) survey. The sample consists of mostly old thin and thick disk stars, with a minimal contribution from the stellar halo, in the region $6 < R < 16$ kpc, $0.15 < |Z| < 1.5$ kpc. We find that the radial metallicity gradient Δ[Fe/H]/ΔR becomes flat at heights $|Z| > 1$ kpc. In addition, we find that the high-α population, which dominates at large heights |Z| in the inner disk ($R < 10$ kpc), makes up a small fraction of stars in the outer disk ($R > 10$ kpc). The chemical and kinematic properties of high-α stars in the outer disk differ from those in the inner disk, consistent with the high-α population having a short scale length. Our observations are consistent with the predictions for a thick disk formed in situ at high redshift, and the lack of high-α stars at large R and |Z| provides a strong constraint on the strength of radial migration induced by transient spiral arms.

205.04 – **Churning, SEGUE and the Puzzle of Galactic History**

Ralph Schoenrich[1]

[1]*MPA, Germany.*
10:45 AM - 10:57 AM

I will discuss two main lines of advance in understanding the dynamics of the Milky Way: The large Galactic surveys have made possible the detailed study of the full links between chemistry and kinematics of stars, while on the theoretical side radial migration was recognized and understood as an important process shaping the Galactic disc. I will discuss some recent observational discoveries, relate them to their theoretical explanations and predictions and delineate their implications for the history of our Galaxy.

205.05 – **Observational Constraints from the Chemically Divided Galactic Disks**

Young Sun Lee[1], T. C. Beers[1], SEGUE Collaboration

[1]*Michigan State Univ..*
11:00 AM - 11:12 AM

We present measurements of the [α/Fe] ratio, obtained from SDSS/SEGUE medium-resolution spectra of about 17,000 G-type dwarfs, and employ this ratio to separate these stars into likely thin- and thick-disk subsamples. We examine these subsamples for trends of rotational velocity and eccentricity with metallicity, [Fe/H], distance from the Galactic plane, |Z|, and Galactocentric distance, R. Some of the notable findings are that there is a rather strong rotational velocity gradient of -20 to -30 km/s/dex with [Fe/H] for the thin-disk population, and +40 to +50 km/s/dex for the thick-disk population. The rotational velocity decreases with |Z| for both disk components, with similar slopes (-9.0 +\- 1.0 km/s/kpc). A relatively strong gradient of orbital eccentricity with [Fe/H] (about -0.2/dex) is observed for the thick-disk stars, whereas the eccentricity is independent of [Fe/H] for the thin-disk subsample. The shapes of the eccentricity distributions for the thin- and thick-disk populations remain roughly unchanged with |Z|. Comparison with several contemporary models of disk evolution indicates that radial migration seems to have played a vital role in the evolution of the thin-disk population, but probably less so for the thick disk, relative to the gas-rich merger or disk heating scenarios. We emphasize that more physically realistic models and simulations are required to perform

detailed quantitative comparisons. This work was supported in part by grants PHY 02-16783 and PHY 08-22648: Physics Frontiers Center/Joint Institute for Nuclear Astrophysics (JINA), awarded by the U.S. National Science Foundation.

205.06 – **APOGEE -- SDSS-III's Other Milky Way Experiment**

Steven R. Majewski[1]

[1]*Univ. of Virginia.*

11:15 AM - 11:27 AM

The Apache Point Observatory Galactic Evolution Experiment (APOGEE) in SDSS-III is a large-scale, near-infrared, high-resolution ($R \geq 22,500$) spectroscopic survey of the Milky Way (MW)

using a newly-constructed, 300-fiber, cryogenic spectrograph operating over 1.51-1.68μm (i.e., most of the *H*-band). Because of the lower *H* band dust extinction compared to optical wavelengths (A_H/A_V=0.16), APOGEE will effectively pierce through dust obscuration to provide a vast, uniform database of chemical abundances and radial velocities for stars across all Galactic populations (bulge, thin and thick disks, halo). APOGEE started observations in May 2011 and will use the remaining ~3 years of SDSS-III bright time to observe ~100,000 giant star candidates selected from the Two Micron All-Sky Survey (2MASS) down to *H*=11-13.5 across hundreds of sightlines. With its high resolution and *S/N* (>100), APOGEE will determine precision radial velocities (presently 200 m/s accuracy) and accurate abundances for numerous chemical species, including C, N, O and Fe, as well as other α, odd-*Z*, and iron-peak elements. Among the main APOGEE scientific objectives are to:

(1) measure in an unbiased, uniform manner the spatial variations of metallicity distributions and abundance patterns with statistically large samples of MW stars,

(2) study the processes of star formation, feedback, mixing and chemical evolution in the MW with sensitivity to numerous nucleosynthetic pathways,

(3) survey Galactic dynamics, particularly in the bulge and disk, where constraints on the nature and influence of the Galactic bar and spiral arms will be defined,

(4) look for chemodynamical evidence of Galactic substructure from accretion events, postulated by hierarchical formation models to be responsible ultimately for the formation of all MW stellar populations, and

(5) use these extensive chemodynamical data, particularly in the inner Galaxy, to unravel the overall formation and evolution of the MW. The first APOGEE results are in hand and will be highlighted.

206 – Reports from NASA's Program Analysis Groups

Special Session – Room 18D – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

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).

206.01 – **Overview and Context from NASA Headquarters**

Rita M. Sambruna[1], M. Perez[1], D. Hudgins[1]

[1]*NASA HQ.*

10:00 AM - 10:15 AM

In this presentation the current activities of NASA's Astrophysics Program Analysis Groups (PAGs) will be described. The value and impact of these groups, which serve as forums for soliciting and coordinating input and analysis from the scientific community in support of the Astrophysics Division's strategic objectives, will be emphasized. For example, the flow of advisory guidance will be explained, that in the case of the PAGs, their findings and analysis are reported to the Astrophysics Subcommittee (APS), which in turn reports to the NASA Advisory Committee (NAC). Each PAG's objective is to enable direct and regular communication through public meetings that give each science community opportunities to provide scientific and programmatic input. In each PAG, much of the work on specific topics is conducted by Study Analysis Groups (SAGs). NASA Headquarters representatives for the Exoplanet Exploration PAG (ExoPAG), the Cosmic Origins PAG (COPAG), and Physics of the Cosmos PAG (PhysPAG) will be participating at this community meeting.

206.02 – **Report from the Exoplanet Exploration Program Analysis Group (ExoPAG)**

James Kasting[1]

[1]*Pennsylvania State University.*

10:15 AM - 10:35 AM

The ExoPAG has met twice each year for the past 2 years, once in association with the Winter AAS meeting and once separately during the summer. The ExoPAG considers its main task to be helping the Exoplanet Exploration Office respond appropriately to the charges set forth by the Astro_2010 survey and thereby advance the status of exoplanet science. Most of our attention so far has been focused on laying the groundwork for a future exoplanet direct imaging flagship mission to find and characterize Earth-like planets around other stars. Ideally, we would like to fly such a mission during the 2020-2030 decade. If that becomes impossible due to budget shortfalls and cost overruns on other astronomical missions, then our fallback position will be to push for some smaller Probe-class mission to advance exoplanet science.

206.03 – **Cosmic Origins Program Analysis Group -- Charting a Future Course**

Christopher D. Martin[1]

[1]*Caltech.*

10:35 AM - 10:55 AM

The Cosmic Origins Program Analysis Group (COPAG) is constituted by the NASA Astrophysics Subcommittee (ApS) to support community coordination and analysis of scientific and technological issues impacting NASA's Cosmic Origins Program. The principal task in 2011-2012 is to support the analysis of technological priorities for potential future Cosmic Origins strategic missions beyond JWST. In particular COPAG has provided input to ApS in support of the 2011 NRC NASA Technology Roadmap activities and to the new NASA Strategic Astrophysics Technology program. The COPAG met with community members at AAS meetings in January and May, 2011. A community workshop was held at StScI Septt 22-23, 2011. Currently the COPAG has four Study Analysis Groups: A group (SAG#1), tasked with developing Cosmic Origins science objectives for the next generation of missions; SAG#2 tasked with developing technology requirements for a 4-m class UV/Optical/Near IR mission for Cosmic Origins/General Astrophysics and an internal coronograph for Exoplanet Imaging and characterization; SAG#3 tasked with developing technology requirements for a 8-m class UV/Optical/Near IR mission for Cosmic Origins/General Astrophysics and an external occulter for Exoplanet Imaging and characterization; and SAG#4, tasked with developing technology requirements for future Far IR/Sub-mm missions. At the January 2012 Austin AAS meeting we will report on progress in these activities.

206.04 – **Summary of PhysPAG Activities**

Steven M. Ritz[1]

[1]*UC Santa Cruz.*

10:55 AM - 11:15 AM

The Physics of the Cosmos (PCOS) Program Analysis Group (PhysPAG) provides an important interface between the scientific community and NASA in matters related to PCOS objectives. An Executive Committee facilitates the work of several subgroups, including a Technology Science Analysis Group and an Inflation Probe Science Analysis Group. Work is also starting in areas of X-ray, gamma-ray, and gravitational wave astrophysics. The PAG reports to the Astrophysics Subcommittee of the NASA Advisory Council. A summary of PhysPAG activities will be given, along with time for questions and discussion.

207 – Galaxy Clusters

Oral Session – Room 16A – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

207.01 – **A Combined Analysis on Clusters of Galaxies with the Fermi-LAT - Gamma Ray Emission from Cosmic Rays and Dark Matter**

Stephan Zimmer[1], J. Conrad[1], A. Pinzke[2]

[1]*Oskar Klein Centre/ Stockholm University, on behalf the Fermi-LAT Collaboration, Sweden,* [2]*University of California, Santa Barbara.*

10:00 AM - 10:10 AM

Clusters of galaxies are the largest virialized structures in the universe. Radio observations indicate the presence of a relativisitic electron population that can give rise to a distinct gamma-ray signature through scattering with low energy photons. In addition, gamma-rays can result from collisions of cosmic-ray protons with particles in the intracluster medium through subsequent π^0 decay.

Moreover, clusters of galaxies possess high mass-to-light ratios, making them interesting targets for indirect dark matter searches. In this case, gamma rays may be produced from the decay or annihilation of dark-matter particles. In either of these emission scenarios the spectra of gamma rays produced is predicted to be significantly different from those of conventional astrophysical sources and from the diffuse galactic and extra-galactic background emission. Observations with the Fermi-LAT, therefore, have the potential to unambiguously identify these processes in clusters of galaxies. The spectral characteristics of dark-matter annihilation or decay and of cosmic-ray emission are expected to be universal in different clusters, making a combined statistical treatment feasible.

We present a combined likelihood analysis and set limits on the dark-matter annihilation cross section or decay time and on the hadron injection efficiency.

207.02 – **Searching For Non-thermal X-rays In The Brightest X-ray And Radio Galaxy Clusters**

Daniel R. Wik[1], C. Sarazin[2], Y. Zhang[3], W. Baumgartner[1], R. Mushotzky[4], J. Tueller[1], T. Clarke[5]

[1]NASA Goddard Space Flight Center, [2]University of Virginia, [3]Argelander-Institut fu¨r Astronomie, Germany, [4]University of Maryland, [5]Naval Research Lab.

10:10 AM - 10:20 AM

The relativistic electrons generating large-scale radio halos and relics in galaxy clusters must also produce inverse Compton (IC) emission at X-ray energies, a measurement of which can yield a cluster's volume-averaged magnetic field strength B. However, unambiguous IC detections in these clusters are rare at best and complicated by challenging observational limitations. To mitigate these difficulties, we extract spatially coincident spectra at soft and hard energies from the XMM-Newton EPIC and Swift BAT detectors, respectively, to search for non-thermal excesses above clusters' thermal emission. In a sample of the brightest X-ray clusters, drawn from HIFLUGCS, we fail to find convincing evidence for an excess in any of the clusters, either individually or when their spectra are stacked. The subset of clusters with the strongest non-thermal indication, however, are those hosting radio halos and/or relics, which are also the clusters expected to have IC tails. From this subsample of 9 clusters, we expand our sample to include those with the ~30 brightest halos and relics. We stack their spectra to search for stronger statistical evidence of IC emission at hard X-ray energies, which constrains the typical average value of B in these clusters.

On top of institutional funding, we acknowledge support from NASA-funded Suzaku and XMM-Newton grants, as well as the NASA Postdoctoral Program for funding DRW. Also, this work would not be possible without the hard work of the entire Swift BAT survey team, who we heartily thank.

207.03 – **Multi-Wavelength Simulation of the Bullet Cluster**

Craig Lage[1], G. Farrar[1]

[1]New York University.

10:20 AM - 10:30 AM

Galactic cluster mergers are key events in the evolution of structure in our universe. The ongoing Bullet Cluster merger (1E0657-56) is arguably one of the most interesting such events for a number of reasons, including its relatively simple structure and high surface brightness across the electromagnetic spectrum. Because of this, it has been extensively studied observationally, making this an ideal laboratory for the study of the physics of galactic clusters. In this work, we have built a detailed simulation of the merger using both SPH and grid-based codes, and including magnetohydrodynamics, plasma cooling, and adaptive mesh refinement. We constrain the simulation with data gathered from several different observational studies, including gravitational lensing and Chandra X-ray luminosity and temperature maps, then compare with Sunyaev-Zel'dovich effect measurements and cluster halo radio emission. We perform a simultaneous 2D least-squares fit to the observational data sets, rather than comparing only a few features, such as the location of subcluster centroids, as has been done previously. A simple initial configuration using two spherically symmetric clusters with NFW dark matter profiles and isothermal beta plasma profiles is found to give a good fit to the current observational morphology of the merging clusters without the need for unconventional physics or extreme infall velocities. We compare the inferred properties of the initial galaxy clusters to expectations from cosmological simulations and observations; limits on alternatives to ΛCDM and conventional gravity are given. We comment on the importance of magnetic fields and plasma cooling for obtaining a good fit to the observations, and report on the inferred relativistic electron distribution.

207.04D – **Galaxy Cluster Environments of Radio Sources**

Joshua Wing[1], E. Blanton[1]

[1]Boston University.

10:30 AM - 10:50 AM

A large sample of galaxy clusters over a range of both redshift and mass is important in addressing questions of galaxy evolution and cosmology. One method of galaxy cluster detection that has shown potential to high redshifts is the use of bent double-lobed radio sources. Using the Sloan Digital Sky Survey (SDSS), we have examined the optical environments surrounding bent double-lobed radio sources drawn from the Faint Images of the Radio Sky at Twenty-centimeters (FIRST) catalog. We find that more than 60% of bent double-lobed radio sources with optical counterparts in the SDSS are found in rich clusters to a redshift of z~0.5 (the limit to which we can detect cluster member galaxies). We also find that straight double-lobed and single-component radio sources are less likely to be located in rich galaxy clusters, with cluster association rates of ~30% and ~10%, respectively. One possible method for bending double-lobed radio sources is a recent large-scale cluster merger. We investigate the optical substructure of the galaxy cluster environments surrounding a subset of our radio/optical sources and search for a correlation between significant substructure and the bending of the radio lobes. Bent double-lobed radio sources lacking detectable host galaxies (typically luminous, giant elliptical galaxies) in the SDSS make ideal candidates for follow-up study as they are likely to be located in high redshift ($z>0.7$) galaxy clusters. There are 1,049 bent-double radio sources without optical hosts in the SDSS, and given the cluster association rate at low redshift, we expect to find approximately 635 clusters at $z>0.7$ with a wide range of masses. We have performed deep ground-based optical and near-infrared follow-up observations of ~80 of these sources lacking optical hosts in the SDSS, and Spitzer observations for ~650 sources are ongoing.

207.05 – **An XMM-Newton Spatially-Resolved Study of Metal Abundance Evolution in Distant Galaxy Clusters**

Alessandro Baldi[1], S. Ettori[2], S. Molendi[3], I. Balestra[4], F. Gastaldello[3], P. Tozzi[5]

[1]Astronomy Department - University of Bologna, Italy, [2]INAF - Osservatorio Astronomico di Bologna, Italy, [3]INAF - IASF Milano, Italy, [4]Max-Planck-Institut fur Extraterrestrische Physik, Germany, [5]INAF - Osservatorio Astronomico di Trieste, Italy.

10:50 AM - 11:00 AM

We present an XMM-Newton study of 39 distant clusters of galaxies ($0.4 < z < 1.4$) performing a spatially resolved X-ray spectral analysis. We did not observe a statistically significant abundance evolution with redshift. The most significant deviation from no evolution (at a 90% c.l.) is observed considering the emission from the whole cluster ($r < 0.6$ R500), that could be parametrized as $Z \sim Z0*(1+z)^{-0.8\pm0.5}$.

Dividing the emission in three radial bins, no significant evidence of abundance evolution could be observed fitting the data with a power-law. A substantial agreement with measures presented in previous works is found.

Computing error-weighted mean of the spatially resolved abundances in three redshift bins, we found it consistent to be constant with the redshift. Although the large error bars in the measure of the weighted-mean abundance prevented us from claiming any statistically significant spatially resolved evolution, the trend with z in the 0.15-0.4 R500 radial bin complements nicely the measures of Maughan et al. (2008), and broadly agrees with theoretical predictions. We also found that the data points derived from the spatially resolved analysis are well fitted by a function of both radius and redshift $Z=f(r,z)$, which shows a significant negative trend of Z with the radius and no significant evolution with the redshift. The present study is the first attempt made to spatially resolve the evolution of abundance with redshift. However, the sample size and the low statistics associated with most of the clusters in the sample prevents us to draw any statistically significant conclusion on the different evolutionary path that the different regions of the clusters may have traversed.

207.06D – **AGN Feedback In Highly-luminous Clusters Of Galaxies**

Julie Hlavacek-Larrondo[1], A. C. Fabian[1]

[1]University of Cambridge, United Kingdom.

11:00 AM - 11:20 AM

Highly-luminous cool core clusters of galaxies require extreme mechanical feedback from their central AGN to offset cooling of the intracluster plasma ($L_{mech}>10^{45}$ erg/s). These systems therefore provide a unique opportunity to study the extreme side of AGN feedback, noticeably through the properties of their AGN outflows, known as X-ray cavities. I present work examining X-ray cavities in such systems.

More precisely, I present the first statistical study of X-ray cavities in distant clusters of galaxies ($z>0.3$). With the aim of providing further insight into how AGN feedback operates at higher redshift, I have analysed the Chandra X-ray observations of the Massive Cluster Survey (MACS). This sample consists of highly-luminous clusters of galaxies within $0.3<z<0.7$, and out of 76 clusters, I find 21 with X-ray cavities. More importantly, I find no evidence for evolution in any of the cavity properties with redshift, implying that extreme “radio mode” feedback ($L_{mech}>10^{45}$ erg/s) starts to operate as early as 7-8 Gyr after the Big Bang and shows no sign of evolution since then. These results have important ramifications for galaxy formation and evolution models.

I also discuss the implications these results have with regards to the masses of the black holes that power these outbursts, and provide evidence that some may be ultramassive ($>10^{10}$ Msol) as oppose to supermassive (10^{9} Msol).

207.07 – **The Redshift Evolution of Optically-Emitting BCGs: An Indirect Probe of Cool Core Evolution?**

Michael McDonald[1]
[1]*MIT.*
11:20 AM - 11:30 AM

The presence of a cool, dense core in the intracluster medium indicates that cooling has dominated over feedback for the past few Gyr. The fraction of galaxy clusters which harbor cool cores is, thus, an important diagnostic of the heating/cooling balance across cosmic time. In this presentation, I will discuss recent work on the evolution of warm, optical line-emitting gas in the cores of galaxy clusters and how this can be used to indirectly probe the evolution of cool cores. Using optical spectra from the Sloan Digital Sky Survey, we find a strong decrease in the fraction of brightest cluster galaxies (BCGs) with optical line-emission from z=0 to z=0.3. At $z > 0.3$, there is evidence for an increase in the number of optically-emitting BCGs. We find that the evolving fraction of optically-emitting BCGs is in excellent agreement with the X-ray-determined cool core evolution over the range $0 < z < 0.6$. This technique may allow for the identification of cool cores at high redshift, where X-ray-based methods are more challenging.

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208 – Star Formation I

Oral Session – Room 12A – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

208.01 – **Finding the Root of Rapid Star Formation**

Eve J. Lee[1], P. Chang[2], N. Murray[3]
[1]*University of Toronto, Canada,* [2]*University of Wisconsin - Milwaukee,*
[3]*Canadian Institute of Theoretical Astrophysics, Canada.*
10:00 AM - 10:10 AM

Classically, star formation was thought to be a slow and inefficient process with only 2% of giant molecular cloud (GMC) mass turning into stars in a free-fall time. Turbulent support, magnetic support, and dispersal of gas via stellar feedback are proposed as the cause of this low star formation efficiency (SFE). Recent numerical simulations and observations, however, suggest a much more rapid star formation process with SFE at ~10-20% or more. The driver of the high SFE remains a question, however. We perform a 16pc-scale numerical simulation of driven, supersonic, self-gravitating, hydrodynamic turbulence with the formation of star particles. We confirm high SFE and propose that the self-gravity of gas is the dominant driver of the rapid star formation.

208.02 – **The Growth of Supermassive Stars by Rapid Accretion of Primordial Gas**

Jarrett L. Johnson[1], D. J. Whalen[2], H. Li[1]
[1]*Los Alamos National Laboratory,* [2]*Carnegie Mellon University.*
10:10 AM - 10:20 AM

Supermassive stars, with masses exceeding 10,000 times the mass of the Sun, are predicted to form within a small fraction of primordial protogalaxies at redshifts $z > 10$. As these objects would collapse to form similarly massive black holes, they are promising candidates for the seeds of supermassive black holes, some of which are inferred to have grown to a billion solar masses by $z \sim 7$. Here we consider the processes that set the maximum mass that such stars can attain by the accretion of primordial gas. We find that the strong ionizing radiation emitted from massive primordial stars can eventually shut off their growth at relatively low accretion rates. However, the upper mass limit for supermassive stars is set by their main sequence lifetime, which becomes very short at high accretion rates.

208.03D – **Exploring the Limits of Star Formation from the Extreme Environment of Starbursts to the Milky Way**

Amanda L. Heiderman[1]
[1]*University of Texas at Austin.*
10:20 AM - 10:40 AM

We investigate the relation between star formation rate (SFR) and gas surface densities in Galactic star forming regions and integral field unit (IFU) spatially resolved regions in nearby interacting/starburst galaxies. Our Galactic study uses a sample of 20 molecular clouds from the Spitzer c2d and Gould's Belt surveys. These data allow us to probe the low mass star formation regime that is essentially invisible to tracers (such as H-alpha emission) used to establish extragalactic relations (eg., Schmidt-Kennicutt relation). We find Galactic clouds above a threshold of 129 Msun/pc^2 lie on a linear relation above extragalactic relations. Our extragalactic IFU survey is the VIRUS-P Investigation of the eXtreme ENvironments of Starbursts (VIXENS) which includes 15 nearby interacting/starburst galaxies that span a range of interaction phases: from close pairs to late stage mergers. The main goal of VIXENS is to investigate the Schmidt-Kennicutt relation on spatial scales of 0.1-0.9 kpc and test theoretical predictions at high SFR and gas surface densities in starburst galaxies. If a starburst CO-to-H2 conversion factor is used, we find sub-kpc scale starburst regions lie above extragalactic relations, overlapping with global measurements of high-z mergers as well as Galactic star forming regions. The overlap with Galactic star forming regions suggests that the bulk of gas in mergers is efficiently forming stars. These unique data sets allow us to compare SFR-gas surface density relations from Galactic clouds to extreme starbursts on spatially resolved scales for the first time.

208.04 – **How Starless are Starless Cores?**

Scott Schnee[1], J. Di Francesco[2], M. Enoch[3], R. Friesen[1], D. Johnstone[2], S. Sadavoy[4], L. Wei[5]
[1]*NRAO,* [2]*NRC-HIA, Canada,* [3]*UC Berkeley,* [4]*University of Victoria, Canada,* [5]*CfA.*
10:40 AM - 10:50 AM

We present the results of recent CARMA and SMA continuum and spectral line observations of dense cores in the Perseus and Ophiuchus molecular clouds. Although these cores have previously been classified as starless, we find evidence for outflows from a significant fraction of the cores, indicating that they are actually embedded, low-luminosity protostars. We discuss the impact of newly discovered low-luminosity embedded objects on starless core and protostar lifetimes. We suggest that high resolution (sub)millimeter surveys of known cores lacking near-infrared and mid-infrared emission are necessary to make an accurate census of starless cores.

208.05 – **On the Stability of Radiation Pressure Dominated Cavities in the Formation of Massive Stars**

Rolf Kuiper[1]
[1]*Jet Propulsion Laboratory.*
10:50 AM - 11:00 AM

Context: Once massive stars exert a radiation pressure onto their environment higher than gravitational attraction, they launch a radiation pressure driven outflow, which creates cleared polar cavities. Where as such cavities would shield further accretion onto the star from the direction of the bubble, it has been claimed that a radiative Rayleigh-Taylor instability would lead to the collapse of the outflow cavity.

Aims: We investigate the stability of radiation pressure dominated cavities, focusing on its dependence on the radiation transport approach used in numerical simulations.

Methods: We compare two different methods for stellar radiation feedback: gray Flux-Limited Diffusion (FLD) and frequency-dependent Ray-Tracing (RT). Both methods are implemented in our self-gravity radiation-hydrodynamics simulations for various initial density structures of the collapsing clouds. We also derive simple analytical models to support our findings.

Results: Both methods lead to the launch of a radiation pressure dominated outflow cavity. But only FLD cases lead to prominent instability in the cavity shell. The RT cases do not show such instability; once the outflow started, it precedes continuously. The FLD cases display extended epochs of marginal Eddington equilibrium in the cavity shell, making them prone to the radiative Rayleigh-Taylor instability. In the RT cases, the radiation pressure exceeds gravity by 1-2 orders of magnitude. Then the radiative Rayleigh-Taylor instability is consequently suppressed. It is a fundamental property of the gray FLD method to neglect the stellar radiation temperature at the location of absorption and thus to underestimate opacity at the location of the cavity shell.

Conclusions: Treating the stellar irradiation in the gray FLD approximation underestimates the radiative forces acting on the cavity shell. This can artificially lead to situations unstable to the radiative Rayleigh-Taylor instability. The proper treatment of direct stellar irradiation by massive stars is crucial for the stability of radiation pressure dominated cavities.

208.06D – **Evidence Of Episodic Mass Accretion In Low-luminosity, Embedded Protostars**

Hyo Jeong Kim[1], N. J. Evans, II[1], M. M. Dunham[2], J. Lee[3]
[1]*The University of Texas at Austin,* [2]*Yale University,* [3]*Kyung Hee University, Korea, Republic of.*
11:00 AM - 11:20 AM

We present Spitzer IRS spectroscopy of CO_2 ice toward 19 young stellar objects (YSOs) with luminosity lower than 1 L_{sun}. Pure CO_2 ice forms only at elevated temperature, $T > 20$ K, and thus at higher luminosity. Pure CO_2 ice formation processes are irreversible. It will not disappear unless it evaporates. Current internal luminosities of YSOs with $L < 1$ L_{sun} do not provide such conditions out to radii of typical envelopes. Significant amounts of pure CO_2 ice would signify a higher past luminosity. We analyze 15.2 micron CO_2 ice bending mode absorption lines in comparison to the laboratory data. We decompose pure CO_2 ice from 15 out of 19 young low luminosity sources. Eight sources show a significant double peak in the optical depth, which provides unambiguous evidence for pure CO_2 ice. The presence of the pure CO_2 ice component indicate high dust temperature and hence high luminosity in past. The total CO_2 ice amount can be explained by long period of low luminosity stage between episodic accretion bursts as predicted in an episodic accretion scenario. Chemical modeling

shows that the episodic accretion scenario explains the observed total CO_2 ice amount best. A detailed analysis has been performed for one low luminosity Class 0 object CB130-1-IRS1. A full SED fitting with a radiative transfer model shows that the internal luminosity of CB130-1-IRS1 is as low as 0.14 - 0.16 L_{sun}. The best fitting chemical evolution model requires episodic accretion and the formation of CO_2 ice from CO ice during the low luminosity periods. This process removes C from the gas phase, providing a much improved fit to the observed gas-phase molecular lines and the CO_2 ice absorption feature. Also we detected the pure CO_2 ice component around CB130-1-IRS1, which is an evidence of past heating.

208.07 – **Testing the Environmental Dependence of the Stellar Initial Mass Function - the Case of L1641**

Wen-hsin Hsu[1], L. Hartmann[1], L. Allen[2], J. Hernandez[3], T. Megeath[4]

[1]*University of Michigan,* [2]*National Optical Astronomy Observatory,* [3]*Centro de Investigaciones de Astronomia, Venezuela, Bolivarian Republic of,* [4]*University of Toledo.*

11:20 AM - 11:30 AM

To test the proposition that the stellar initial mass function (IMF) depends on the environmental density, we conducted an optical spectroscopic and photometric survey of the young stellar population in L1641, a low-density, star-forming region of the Orion A cloud south of the dense Orion Nebula Cluster (ONC).

We used low-resolution optical spectra and optical photometry, as well as the Spitzer IRAC photometry (Megeath et al. 2011) to identify members and obtain spectral types. As of now, we have confirmed and spectral-typed 648 members and project a total number of 780 members with moderate extinction.

Our study suggests a comparison between L1641 and the ONC can yield a statistically-significant test of the dependence of the upper mass portion of the stellar initial mass function upon environment. Our preliminary results indicate that L1641 may well be deficient in O and early B stars.

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209 – AGN, QSO, Blazars III

Oral Session – Room 17A – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

209.01 – **Anomalous Narrow-line Quasars**

Charles Steinhardt[1], J. Silverman[1]

[1]*IPMU, University of Tokyo, Japan.*

10:00 AM - 10:10 AM

Anomalous narrow-line quasars are a new class of Type I quasars with narrow Hβ broader than 1200 km/s, above the velocity believed possible for gas in the quasar narrow-line region. This broadening is tightly correlated with changes in other spectral features, so that the set of ANLs is a distinct population difficult to explain with the current quasar standard model. Further, ANLs comprise over one quarter of all quasars at $0.2 < z < 0.8$, so they must be accounted for as part of our understanding of supermassive black hole evolution. Because other quasar narrow lines such as [O II] are diminished or disappear entirely, ANLs raise several fundamental questions about the connection between the black hole and the central region of the galaxy. They also appear inconsistent with a predominantly virial broad-line region, calling into question the technique of virial mass estimation.

209.02D – **The Nature Of Microvariability Of Blazar 0716+714.**

Gopal Bhatta[1]

[1]*Florida International University.*

10:10 AM - 10:30 AM

The international WEBT (The Whole Earth Blazar Telescope) consortium planned and carried out three days of intensive micro-variability observations of 0716+71 from February 22, 2009 to February 25, 2009. This object was chosen due to its bright apparent magnitude range (~12-14 magnitudes in R), its high declination, and its very large duty cycle for micro-variations (Webb et al.2008). Thirty-six observatories in sixteen countries around the world participated in this continuous monitoring program and submitted data for compilation into a continuous light curve and subsequent analysis. We report here on the long continuous optical micro-variability light curve of 0716+71 obtained during the multi-site observing campaign during which the Blazar showed almost constant variability over a 0.5 magnitude range. The resulting reduced light curve is presented here for the first time. Individual observations from observatories were corrected for instrumental differences and the overall smoothed light curve was constructed from the highest quality data. The resulting nearly continuous light curve was analyzed using several techniques including Fourier transforms and noise analysis techniques. Since we found no repeatable periods consistent with other reports, and the noise analysis did not indicate that the light curve was due to simple stochastic noise, we have interpreted the variations in the light curve in terms of individual stochastic pulses due to cells in a turbulent jet which are energized by a passing shock and cool by means of synchrotron emission. Our work estimates some of the parameters of the Blazar jet like magnetic field, maximum energy of the electron, size of inhomogeneous regions etc. Such estimations help to understand the underlying physical processes in the jet and ultimately in the Blazar itself.

209.03 – **FIRST-2MASS Red Quasars: Transitional Objects Emerging from the Dust**

Eilat Glikman[1], M. Lacy[2], T. Urrutia[3], G. Djorgovski[4], A. Mahabal[4]

[1]*Yale University,* [2]*NRAO,* [3]*Astrophysikalisches Institut Potsdam, Germany,* [4]*Caltech.*

10:30 AM - 10:40 AM

We have identified a sample of ~120 dust-reddened quasars by matching radio sources detected at 1.4 GHz with the near-infrared 2MASS catalog and color-selecting red sources. Optical and/or near-infrared spectroscopy provide broad wavelength sampling of their spectral energy distributions that we use to determine their reddening, E(B-V). This sample spans a wide range in redshift and reddening ($0.1 < z < 3$, $0.1 < E(B-V) < 1.5$), which we use to investigate the effect of luminosity on reddening and its evolution with redshift. At every redshift, dust-reddened quasars are intrinsically the most luminous quasars. We interpret this in the context of merger-driven quasar/galaxy co-evolution where these reddened quasars are revealing an emergent phase where the heavily obscured quasar is shedding its cocoon of dust prior to becoming a "normal" blue quasar. We estimate, based on the fraction of objects in this phase, that its duration is ~ 20% as long as the unobscured, blue quasar phase.

209.04 – **The Lick AGN Monitoring Project 2011: Reverberation Mapping of Markarian 50**

Aaron J. Barth[1], A. Pancoast[2], LAMP2011 Collaboration

[1]*UC Irvine,* [2]*UCSB.*

10:40 AM - 10:50 AM

The Lick AGN Monitoring Project 2011 observing campaign was carried out over the course of 11 weeks in Spring 2011. Here we present the first results from this program, a measurement of the broad-line reverberation lag in the Seyfert 1 galaxy Mrk 50. Combining our data with supplemental observations obtained prior to the start of the main observing campaign, our dataset covers a total duration of 4.5 months. During this time, Mrk 50 was highly variable, exhibiting a maximum variability amplitude of a factor of 4 in the U-band continuum and a factor of 2 in the H-beta line. Using standard cross-correlation techniques, we find that H-beta and H-gamma lag the V-band continuum by 10.64(-0.93,+0.82) and 8.43(-1.28,+1.30) days, respectively, while the lag of He II 4686 is unresolved. The H-beta line exhibits a symmetric velocity-resolved reverberation signature with shorter lags in the high-velocity wings than in the line core, consistent with an origin in a broad-line region dominated by orbital motion rather than infall or outflow. Assuming a virial normalization factor of f=5.25, the virial estimate of the black hole mass is $(3.2+/-0.5)*10^7$ solar masses. These observations demonstrate that Mrk 50 is among the most promising nearby active galaxies for detailed investigations of broad-line region structure and dynamics.

209.05 – **The Lick AGN Monitoring Project 2011: Dynamical Modeling of the Broad Line Region in Mrk 50**

Anna Pancoast[1], B. J. Brewer[1], T. Treu[1], LAMP2011 Collaboration

[1]*University of California Santa Barbara.*

10:50 AM - 11:00 AM

We present dynamical modeling of the broad line region (BLR) in the Seyfert 1 galaxy Mrk 50, using reverberation mapping data taken as part of the Lick AGN Monitoring Project 2011. We model the reverberation mapping data directly, constraining the geometry and kinematics of the BLR, as well as deriving a black hole mass estimate that does not depend on a normalizing factor or virial coefficient. We find that the geometry of the BLR in Mrk 50 is a nearly face-on thick disk, with a mean radius of ~10 light days. We also constrain the inclination angle to be ~80 degrees, closer to face-on. Finally, we measure the black hole mass to a precision of 0.4 dex. We compare our inferred black hole mass to the virial black hole mass, $Mvir = (f\ v^2\ c\ tau)/G$, measured from traditional reverberation mapping analysis, also constraining the normalizing coefficient, f, to within 0.4 dex. While our dynamical model includes the possibility of a net inflow or outflow in the BLR, we find a slight preference for outflow.

209.06 – **The SDSS-III BOSS DR9 Quasar Luminosity Function**

Nicholas Ross[1], I. D. McGreer[2], M. White[1], A. M. Myers[3], G. T. Richards[4], M. A. Strauss[5], S. F. Anderson[6], S. Bailey[1], X. Fan[2], N. Palanque-Delabrouille[7], P. Petitjean[8], K. Schawinski[9], D. P. Schneider[10], J. Silverman[11], D. H. Weinberg[12], C. Yeche[7], D. G. York[13]

[1]*Lawrence Berkeley National Lab,* [2]*Steward Observatory, University of Arizona,* [3]*University of Wyoming,* [4]*Drexel University,* [5]*Princeton University,* [6]*University of Washington,* [7]*CEA, Centre de Saclay, IRFU, France,* [8]*IAP, Universite Paris 6 et CNRS, France,* [9]*Yale University,* [10]*Pennsylvania State University,* [11]*IPMU, University of Tokyo, Japan,* [12]*Ohio State University,* [13]*University of Chicago.*
11:00 AM - 11:10 AM

We calculate and present the quasar luminosity function (QLF) using data from 30,000 new, z>2 quasars from the SDSS-III: Baryon Oscillation Spectroscopic Survey (BOSS). The BOSS data, along with the original SDSS-I/II, and the 2SLAQ QSO survey, will help cover luminosity-redshift (L-z) plane, such that there is a ~4 magnitude dynamic range from redshifts z=0-4. In particular, the g=22.0 BOSS quasars fill in the z=2.2-3.5 redshift range, key for investigations for the faint-end of the QLF at the height of the ``quasar epoch''. We use our new measurements to map the black hole accretion history of the Universe and constrain how quasars contribute to the ``AGN feedback'' cycle in galaxy formation.

209.07 – **The z~5 Quasar Luminosity Function From SDSS Stripe 82**

Ian D. McGreer[1], L. Jiang[2], X. Fan[1], N. P. Ross[3], M. R. Eskew[4], A. D. Myers[5], D. P. Schneider[6]

[1]*University of Arizona,* [2]*Arizona State University,* [3]*Lawrence Berkeley National Laboratory,* [4]*University of Texas, Austin,* [5]*University of Wyoming,* [6]*The Pennsylvania State University.*
11:10 AM - 11:20 AM

High redshift quasars mark the growth of supermassive black holes in the early universe, and determining the evolution of the quasar population at high redshift provides strong constraints on early structure formation and the buildup of massive galaxies. The SDSS-III BOSS is now providing the best measurements of the quasar luminosity function (QLF) at $2.2 < z < 3.5$, but is not designed to probe higher redshifts. Using the many epochs of SDSS imaging available in the Stripe 82 region we have identified a large number of z~5 quasar candidates to a depth of i(AB)=22, and are confirming these objects with BOSS spectra obtained through ancillary science programs, as well as observations at the MMT and Magellan telescopes. These observations probe much deeper into the QLF than previous surveys at these redshifts and provide a key connection between lower redshift results and the highest redshift quasars at z=6-7.

209.08 – **The Space Density of X-ray Selected AGN in Stripe 82**

Stephanie M. LaMassa[1], C. M. Urry[1], E. Glikman[1], F. Santana[2], B. Lundgren[1], N. Padmanabhan[1], K. Schawinski[1], B. Simmons[1], E. Treister[3], D. Wake[1]

[1]*Yale University,* [2]*Universidad de Chile, Chile,* [3]*Universidad de Concepción, Chile.*
11:20 AM - 11:30 AM

The large survey area of Stripe 82 allows for the inclusion of rare high luminosity and high redshift AGN that are under-represented in deep, smaller area surveys. Based on matching archival XMM-Newton and Chandra data to the Sloan Digital Sky Survey, we compare the number counts of X-ray selected AGN in Stripe 82 to smaller, lower-luminosity samples from the Chandra Deep Fields, GOODS, COSMOS, and AEGIS. We differentiate between obscured and unobscured AGN in Stripe 82 and model these populations with an evolving luminosity function. Finally, we comment on the high luminosity end of the X-ray selected quasar luminosity function, probing a population previous surveys are unable to explore fully.

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210 – Education, Outreach, and Citizen Science

Oral Session – Room 18A – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

210.01 – **CAISE: A NSF Resource Center for Informal Science Education**

Benjamin Dickow[1]

[1]*OSU/ CAISE.*
10:00 AM - 10:10 AM

Informal science education (ISE) is playing an increasingly important role in how and where the public engages with science. A growing body of research is showing that people learn the majority of their science knowledge outside of school (Falk & Dierking, 2010). The ISE field includes a wide variety of sources, including the internet, TV programs, magazines, hobby clubs and museums. These experiences touch large numbers of people throughout their lifetimes.

If you would like to share your research with the public, ISE can be an effective conduit for meaningful science communication. However, because the ISE field is so diverse, it can be overwhelming with its multiple entry points. If you already are part of an ISE initiative, knowing how to access the most useful resources easily can also be daunting. CAISE, the Center for Advancement of Informal Science Education, is a resource center for the ISE field funded by the National Science Foundation (NSF). CAISE can help connect you to the knowledge and people of ISE, through its website, products and in-person convenings.

The proposed CAISE presentation will outline the diversity of the field and concisely present data that will make the case for the impact of ISE. We will focus on examples of successful programs that connect science with the public and that bring together AAS's science research community with practitioners and researchers within ISE. Pathways to various ISE resources in the form of current CAISE initiatives will be described as well.

The presentation will include an interview section in which a CAISE staff member will ask questions of a scientist involved in an ISE initiative in order to detail one example of how ISE can be a valuable tool for engaging the public in science. Time for audience Q&A also will be included in the session.

210.02 – **"Come For The Festival, Eh?" Science Festivals As Public Outreach Venues.**

Jim Manning[1], G. Schultz[1], S. Gurton[1], A. Fraknoi[1]

[1]*Astronomical Society of the Pacific.*
10:10 AM - 10:20 AM

Science festivals are proliferating as a means to engage the public in science over a period of several days or longer through a wide variety of talks, exhibits, tours, interactive activities and other types of public events. The presenter will relate the experience of the Astronomical Society of the Pacific as an institutional partner in the Bay Area Science Festival, held October 29 through November 6, 2011 in the San Francisco Bay Area, and will offer both perspectives and lessons learned about the value of such festivals as a means of public engagement in science.

210.03 – **Advertising Citizen Science: A Trailer for the Citizen Sky Project**

Ryan Wyatt[1], A. Price[2]

[1]*California Academy of Sciences,* [2]*American Association of Variable Star Observers.*
10:20 AM - 10:30 AM

Citizen Sky is a multi-year, NSF funded citizen science project involving the bright and mysterious variable star epsilon Aurigae. The project was conceived by the IYA 2009 working group on Research Experiences for Students, Teachers, and Citizen-Scientists. Citizen Sky goes beyond simple observing to include a major data analysis component, introducing participants to the full scientific process from background research to paper writing for a peer-reviewed journal. As a means of generating interest in the project, the California Academy of Sciences produced a six-minute "trailer" formatted for both traditional and fulldome planetariums as well as HD and web applications. This talk will review the production process for the trailer as well as the methods of distribution via planetariums, social media, and other venues–along with an update on the Citizen Sky Project as a whole.

We will show how to use a small, professionally-produced planetarium trailer to help spread word on a citizen science project. We will also show preliminary results on a study about how participation level/type in the project affects science learning.

210.04D – **Changes in Participants' Scientific Attitudes and Epistemological Beliefs During an Astronomical Citizen Science Project**

Aaron Price[1]

[1]*AAVSO/Tufts University.*
10:30 AM - 10:50 AM

Citizen science projects offer opportunities for non-scientists to take part in scientific research. While their contribution to scientific data collection has been well documented, there is limited research on changes that may occur to their volunteer participants. In this study, we investigated (1) how volunteers' attitudes towards science and beliefs in the nature of science changed over six months of participation in an astronomy-themed citizen science project and (2) how the level of project participation accounted for these changes. To measure attitudes towards science and beliefs about the nature of science, identical pre- and post-tests were used. We used pre-test data from 1,375 participants and post-test data collected from 175 participants. Responses were analyzed using the Rasch Rating Scale Model. The pre-test sample was used to create the Rasch scales for the two scientific literacy measures. For the pre/post-test comparisons, data from those who completed both tests were used. Fourteen participants who took the pre/post-tests were interviewed. Results show that overall scientific attitudes did not change, $p = .812$. However, we did find significant changes related towards two scientific attitude items about science in the news (positive change; $p < .001$, $p < .05$) and one related to scientific self-efficacy (negative change, $p < .05$). These changes were related to the participants' social activity in the project. Beliefs in the nature of science significantly increased between the pre- and post-tests, $p = .014$. Relative positioning of individual items on the belief scale did not change much and this change was not related to any of our recorded project activity variables. The interviews suggest

that the social aspect of the project is important to participants and the change in self-efficacy is not due to a lowering of esteem but rather a greater appreciation for what they have yet to learn.

210.05 – **Is Amateur Astronomers' Astronomy Knowledge a Barrier to Successful Outreach?**

Timothy F. Slater[1], S. J. Slater[2], C. A. Price[3], CAPER Center for Astronomy & Physics Education Research

[1]*University of Wyoming,* [2]*CAPER Center for Astronomy & Physics Education Research,* [3]*American Association of Variable Star Observers.*

10:50 AM - 11:00 AM

Considerable effort in astronomy education research has focused on developing assessment tools in the form of multiple-choice conceptual diagnostics and content knowledge surveys. This has been critically important for establishing the initial knowledge state of students and measure impacts of innovative instructional interventions over a universe of topics. Unfortunately, few of the existing instruments were constructed upon a solid list of clearly articulated and widely agreed upon learning objectives that span an entire introductory survey course. Moving beyond the 10-year old Astronomy Diagnostics Test, scholars at the CAPER Center for Astronomy & Physics Education Research developed and validated criterion referenced assessment tool, which is tightly aligned to the consensus learning goals stated by the AAS Chair's Conference on ASTRO 101, the AAAS Project 2061 Benchmarks, and the NRC National Science Education Standards, called the Test Of Astronomy STandards (TOAST). This multiple-choice instrument has a high degree of reliability and validity and is being deployed in a number of formal and informal learning environments. A collaborative research endeavor between the CAPER Team and the American Association of Variable Star Observers measured the astronomy content knowledge amateur astronomers, relative to widely agreed upon learning targets. We uncovered that our sample of 300 amateurs have higher than expected scores on the TOAST, significantly higher than students leaving our top-tier ASTRO 101 survey courses. Given recent learning sciences research demonstrating the potential of highly specialized languages that exist within some communities and rapidly declining membership rolls of formal amateur organizations, these scores could be interpreted as a potential communication barrier existing for engaging novices who are potential future club members. These results suggest that organizations may need to strategically clarify the nature of educational experiences they provide than can serve transformative in order to nurture a more robust pipeline of members.

210.06 – **Bringing Science Public Outreach to Elementary Schools**

Lucas Miller[1], A. Speck[1], A. Tinnin[2]

[1]*University of Missouri,* [2]*The Saint Louis Science Center.*

11:00 AM - 11:10 AM

Many science "museums" already offer fantastic programs for the general public, and even some aimed at elementary school kids. However, these venues are usually located in large cities and are only occasionally used as tools for enriching science education in public schools. Here we present preliminary work to establish exciting educational enrichment environments for public schools that do not easily have access to such facilities. This program is aimed at motivating children's interest in science beyond what they learn in the classroom setting. In this program, we use the experience and experiments/demonstrations developed at a large science museum (in this case, The St. Louis Science Center) and take them into a local elementary school. At the same time, students from the University of Missouri are getting trained on how to present these outreach materials and work with the local elementary schools.

Our pilot study has started with implementation of presentations/demonstrations at Benton Elementary School within the Columbia Public School district, Missouri. The school has recently adopted a STEM (Science, Technology, Engineering, and Mathematics) centered learning system throughout all grade levels (K-5), and is therefore receptive to this effort. We have implemented a program in which we have given a series of scientific demonstrations at each grade level's lunch hour.

Further enrichment ideas and plans include: addition demonstrations, hands-on experiments, and question and answer sessions. However, the application of these events would be to compliment the curriculum for the appropriate grade level at that time.

The focus of this project is to develop public communications which links science museums, college students and local public schools with an emphasis on encouraging college science majors to share their knowledge and to strengthen their ability to work in a public environment.

210.07 – **Keeping the Stars in Our Eyes: Global Astronomy Month's Dark Skies Awareness Programs**

Constance E. Walker[1], Global Astronomy Month's Dark Skies Awareness Working Group

[1]*NOAO.*

11:10 AM - 11:20 AM

The International Year of Astronomy provided opportunities to experience the beauty of the night sky. Every April since IYA2009, Global Astronomy Month (GAM) carried on the activities with new ones. Its goal is to bring astronomy enthusiasts together to celebrate astronomy and the beauty of observing the sky. Dark Skies Awareness (DSA) is a major program of GAM. Its main "take away" message focuses on reasons and methods for preserving the night sky. With half of the world's population living in cities, many people never experience the wonderment of a pristinely dark sky. "Light pollution" is obscuring people's long-standing natural heritage to view stars. Poorly-aimed and unshielded outdoor lights are the cause of most of the light pollution. They waste more than $2 billion (17 billion kilowatt-hours) of energy in the United States each year. Under unpolluted skies we ought to see more than a couple thousand stars, yet we see less than a hundred from many cities. A number of dark skies events and activities to promote public awareness on how to save energy and save our night sky were held worldwide during GAM2011 and will be held during GAM2012:

· International Earth & Sky Photo Contest, April 1-22

· GLOBE at Night, which measures local levels of light pollution over a 10 day period, April 11-20

· International Dark Sky Week, April 14-20

· World Night in Defense of Starlight, April 20

· Dark Sky Rangers, designed to involve young people in preventing light pollution

· One Star at a Time, creating accessible public spaces for viewing a dark night sky

· Dark Skies Awareness 10 minute audio podcasts and poetry

GAM 2012 DSA programs will be presented in terms of lessons learned and plans ahead to redress a disappearing natural heritage-our dark night sky.

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211 – White Dwarfs, Novae, and Cataclysmic Variables

Oral Session – Room 19B – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

211.01 – **A Catalog of 15,000 White Dwarfs Detected in the GALEX Survey**

Sebastien Lepine[1]

[1]*American Museum of Natural History and City University of New York.*

10:00 AM - 10:10 AM

I present a catalog of about 15,000 white dwarfs identified in the GR6 data release of the Galaxy Evolution Explorer (GALEX) source catalog. White dwarfs were searched in GALEX by identifying counterparts of the UV-bright sources in the SUPERBLINK all-sky proper motion catalog, which records stars with proper motions larger than 40 mas/yr to a limiting magnitude R=19. GALEX sources with confirmed, large proper motions were identified as white dwarfs based on their location in a UV-to-optical reduced proper motion diagram. We show this diagram to be significantly more efficient in identifying white dwarfs than pure optical, or optical-to-infrared reduced proper motion diagrams. The bulk of the white dwarfs identified in this program are estimated to be within 200 parsecs of the Sun, and have kinematics consistent with the Galactic thin and thick disk.

211.02 – **The Distance to the Galactic Globular Cluster, 47 Tuc**

Kristin Woodley[1], R. Goldsbury[1], J. Kalirai[2], H. Richer[1], P. Tremblay[3], J. Anderson[2], P. Bergeron[4], A. Dotter[2], L. Esteves[5], G. Fahlman[6], B. Hansen[7], J. Heyl[1], J. Hurley[8], R. Rich[7], M. Shara[9], P. Stetson[6]

[1]*University of British Columbia, Canada,* [2]*STScI,* [3]*Universität Heidelberg, Germany,* [4]*University of Montreal, Canada,* [5]*University of Guelph, Canada,* [6]*Herzberg Institute of Astrophysics, Canada,* [7]*University of California at Los Angeles,* [8]*Swinburne University of Technology, Australia,* [9]*American Museum of Natural History.*

10:10 AM - 10:20 AM

We present a new distance determination to the Galactic globular cluster 47 Tucanae by fitting the spectral energy distributions of its white dwarfs to pure hydrogen atmosphere white dwarf models. Our photometric data set is obtained from a 121 orbit Hubble Space Telescope program using the Wide Field Camera 3 UVIS/IR channels, capturing F390W, F606W, F110W, and F160W images. These images cover more than 60 arcmin^2 and extend over a radial range of 5-13.7 arcmin (6.5-17.9 pc) within the globular cluster. Here, we present our best fitting distance modulus using a likelihood analysis. We also search the white dwarf photometry for infrared excess in the F160W filter, indicative of protoplanetary disks or low mass companions, and find no convincing cases within our sample.

211.03 – **Understanding Abundance Patterns of Cataclysmic Variables in the**

Near Infrared

Ryan T. Hamilton[1], T. E. Harrison[1]

[1]*New Mexico State University.*
10:20 AM - 10:30 AM

We present the progress of an ongoing program to obtain and understand moderate resolution (R > 2000) near infrared (NIR) spectroscopy for all cataclysmic variable (CV) subtypes. Looking in the NIR allows us to directly examine the atmosphere of the donor star in the CV system. In general, pre-CV, magnetic, and short period systems appear to have normal abundances and do not harbor any surprises. A significant fraction of long period systems, however, show weak or absent K-band CO lines.

To fully assess these data, we compute synthetic spectra using either PHOENIX or MOOG. We use a genetic algorithm (GA) to search a multidimensional parameter space efficiently, spanning a large range in effective temperature, surface gravity, metallicity, C12/C13 isotope ratio, and a variety of individual elemental abundances. Of particular interest is the C abundance, which allows us to explore the C deficiencies as shown by weak or absent CO lines in our sample. The GA results have been calibrated against a number of "standard" K and M dwarfs with known abundances and stellar parameters to provide error and confidence estimates.

We present our early results of this observation and modeling program.

211.04D – **Low Mach Number Simulations of Classical Novae**

Brendan K. Krueger[1], A. C. Calder[1], M. Zingale[1], A. S. Almgren[2], J. B. Bell[2], A. Nonaka[2]

[1]*SUNY Stony Brook,* [2]*Lawrence Berkeley National Laboratory.*
10:30 AM - 10:50 AM

Classical novae are thermonuclear explosions in the accreted layer on the surface of a white dwarf star. The manner in which convective flow interacts with the underlying white dwarf plays a critical role in determining the composition of the accreted layer and the energy release in the outburst. Studies of these complex reactive flows are typically limited by the available computing technology. I am applying a new low Mach number simulation code, MAESTRO, to study classical novae. MAESTRO filters out acoustic waves, allowing much larger time steps without restricting temperature or density perturbations, which in turn enables simulations of much longer time scales. With this unique tool, I have been exploring the development of convection and subsequent mixing in classical novae and their impact on the overall evolution of the outburst. I will present results from multidimensional simulations and quantify the character of the convection and mixing. This work was supported by NASA under grant No. NNX09AD19G and LLNL under contract B59328.

211.05 – **Study Of Flashes On H/He Accreting CO White Dwarfs.**

Joseph Mitchell[1], P. Hoeflich[1]

[1]*Florida State University.*
10:50 AM - 11:00 AM

Type Ia Supernovae are important tools for high precision cosmological measurements. There are currently two suggested progenitor systems for Sne Ia, the double degenerate (DD) and single degenerate (SD) scenarios. An open question with the SD system is whether it is possible for the white dwarf to approach the Chandrasekhar mass, without the shell flashes causing the white dwarf to lose the mass it accreted. We will present full hydrodynamical 1-D model with the inclusion of rotational effects for various accretion rates and discuss our results.

211.06 – **Resolving the Remnant in Recurrent Nova V407 Cyg**

Amy J. Mioduszewski[1], L. Chomiuk[2], M. Rupen[1], M. Krauss[1], J. Sokoloski[3], N. Roy[4]

[1]*NRAO,* [2]*Jansky Fellow, Harvard/CfA,* [3]*Columbia Astrophysics Laboratory,* [4]*Jansky Fellow, NRAO.*
11:00 AM - 11:10 AM

On March 10, 2010 the symbiotic binary V407 Cyg went into a outburst. It was immediately observed at many wavelengths both because Gamma-rays were detected for the first time from a nova explosion, but also because it was had a Mira companion, suggesting a dense circumstellar medium. V407 Cyg became a radio source with both thermal and non-thermal components. The radio light curves do not fit theoretical models for nova light curves suggesting that the nova explosion in V407 Cyg does not have a simple evolution. The initial radio images with the VLBA, days to months after the outburst, showed a slightly resolved source which was probably a small part of a much bigger remnant, but the early EVLA observations did not resolve it. New EVLA observations at higher resolution, taken more than a year after outburst, show a resolved remnant about 2 asec in size with several components. We will present these images and show how they will inform the interpretation of this enigmatic object.

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212 – Cosmic Microwave Background

Oral Session – Ballroom D – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

212.01D – **Measuring the CMB Polarization at 94 GHz with the QUIET Experiment**

Raul Monsalve[1]

[1]*University of Miami.*
10:00 AM - 10:20 AM

The Q/U Imaging ExperimenT (QUIET) aims to limit or detect cosmic microwave background (CMB) divergence-free (B-mode) polarization from inflation. This talk is part 1 of a 3-talk series on QUIET.

QUIET operated in the Chilean Atacama desert between August 2008 and December 2010. During its second season it observed with a 90-element W-band receiver at 94 GHz. QUIET's primary goal is the detection of the B-mode polarization of the CMB predicted by inflationary models. This is one of the great objectives of the current generation of cosmology experiments. In order to realize the extremely low signal levels necessary to detect B-mode polarization, QUIET has incorporated a number of novel design features that have combined to minimize systematic effects. Some of these include an all-enshrouding, absorbing ground screen, side-fed Dragonian optics, platelet arrays of corrugated feedhorns, low crosstalk septum polarizers, compact MMIC modules and a double demodulation scheme. The talk provides an overview of the science goals and a description of the instrument, scanning strategies and calibration techniques. It also presents a straightforward approach to extracting and understanding low level instrumental polarization which can ultimately hamper these types of measurements. The next talks will provide an overview of the two parallel pipelines used in the QUIET data analysis.

212.02D – **Measuring The cmb Polarization At 94 GHz With The QUIET Pseudo-c$_L$ Pipeline**

Immanuel Buder[1], QUIET Collaboration

[1]*University of Chicago.*
10:20 AM - 10:40 AM

The Q/U Imaging ExperimenT (QUIET) aims to limit or detect cosmic microwave background (CMB) B-mode polarization from inflation. This talk is part of a 3-talk series on QUIET. The previous talk describes the QUIET science and instrument. QUIET has two parallel analysis pipelines which are part of an effort to validate the analysis and confirm the result. In this talk, I will describe the analysis methods of one of these: the pseudo-C$_l$ pipeline. Calibration, noise modeling, filtering, and data-selection choices are made following a blind-analysis strategy. Central to this strategy is a suite of 30 null tests, each motivated by a possible instrumental problem or systematic effect. The systematic errors are also evaluated through full-season simulations in the blind stage of the analysis before the result is known. The CMB power spectra are calculated using a pseudo-C$_l$ cross-correlation technique which suppresses contamination and makes the result insensitive to noise bias. QUIET will detect the first three peaks of the even-parity (E-mode) spectrum at high significance. I will show forecasts of the systematic errors for these results and for the upper limit on B-mode polarization. The very low systematic errors in these forecasts show that the technology is ready to be applied in a more sensitive next-generation experiment. The next and final talk in this series covers the other parallel analysis pipeline, based on maximum likelihood methods. This work was supported by NSF and the Department of Education.

212.03D – **Measuring the CMB Polarization at 94 GHz with the QUIET Maximum Likelihood Pipeline**

Sigurd Naess[1], QUIET collaboration

[1]*Oslo University, Norway.*
10:40 AM - 11:00 AM

The Q/U Imaging ExperimenT (QUIET) aims to limit or detect microwave background (CMB) B-mode polarization from inflation. This talk is part 3 of a 3-talk series on QUIET.

QUIET has two parallel analysis pipelines which are part of an effort to validate the analysis and confirm the result. In this talk, I will describe the analysis methods of one of these: the maximum likelihood pipeline. This pipeline has two main steps: First, a map-making step produces unbiased, minimum-variance maps and their corresponding covariance matrices. Unbiased maps with known statistical properties are useful for foreground analysis, but also allows the following Gibbs sampling based power spectrum estimation step to sample from the exact posterior distribution. I will discuss the 94 GHz results from the ML pipeline in context with the 43 Ghz results and the pseudo-Cl pipeline results.

212.04 – **Exploring CMB Polarization with POLARBEAR**

Aubra E. Anthony[1], POLARBEAR

[1]*University of Colorado.*
11:00 AM - 11:10 AM

POLARBEAR is a ground-based experiment built to study polarization of the cosmic microwave background, using an array of 1274 antenna-coupled superconducting transition edge sensor (TES) bolometers mounted on the Huan Tran Telescope (HTT). POLARBEAR has 3.8-arcminute beam resolution at 150 GHz, allowing for measurements of a gravitational lensing signal at small angular scales, and simultaneously enabling the search for evidence of gravitational waves due to inflation at large angular scales. POLARBEAR has been designed to have exceptionally low systematics and high sensitivity, and is projected to reach a tensor-to-scalar ratio of 0.025 after two years of observation. After a successful engineering run in the Inyo Mountains of California in 2010, POLARBEAR is now sited at the Atacama Desert in Chile, where observations will begin in late 2011. I will report on the current status of the POLARBEAR experiment, and discuss plans for the 2012 observing season. The POLARBEAR experiment is funded by the National Science Foundation under grant AST-0618398.

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213 – HEAD III: New Results from the Fermi Observatory

Oral Session – Room 18B – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

213.01 – **Fermi-lat Searches For Radio-quiet Millisecond Pulsars**

Pablo Saz Parkinson[1], M. Dormody[1], A. Belfiore[1], M. Razzano[1]

[1]*UC, Santa Cruz.*
10:00 AM - 10:10 AM

The Large Area Telescope (LAT) on Fermi has detected ~100 gamma-ray pulsars, including a large number of radio-quiet, Geminga-like pulsars and a population of gamma-ray millisecond pulsars (MSPs.). So far, however, no radio-quiet MSPs have been uncovered by the LAT. Searches for radio-quiet MSPs are computationally challenging and are hampered by the relatively large uncertainties in the LAT positions. I will discuss the latest status and prospects of our blind searches for radio-quiet MSPs with the LAT.

213.02 – **Supernova Remnants Interacting With Molecular Clouds: New Observations With The Fermi-LAT**

Daniel Castro[1]

[1]*MIT Kavli Institute.*
10:10 AM - 10:20 AM

Supernova remnant (SNR) shocks are expected to be sites of cosmic rays acceleration, and clouds of dense material can provide effective targets for production of gamma-rays from proton-proton interactions and subsequent pion decay. There exists a population of SNRs which show evidence of interaction with molecular clouds, and we report on a study of the gamma-ray emission coincident with these supernova remnants using data from the Large Area Telescope on board the Fermi Gamma-ray Space Telescope. Detailed spatial and spectral analysis of the Fermi LAT observations in the regions of these SNRs provides constraints on the origin of the gamma-ray emission.

213.03 – **Fermi-LAT Observations of Supernova Remnants**

Theresa Brandt[1], Fermi LAT-Collaboration

[1]*NASA Goddard Space Flight Center.*
10:20 AM - 10:30 AM

With only a few years' data, the Fermi Gamma-ray Space Telescope has already provided a wealth of new GeV-detected Supernova Remnants (SNRs). Long held as suspects for galactic cosmic ray (CR) acceleration, emission up to 100 TeV implies that at least some of the SNRs can contribute to the galactic CR population. With well-resolved spectra and morphological studies, Fermi-LAT data allows us to better characterize the SNRs' particle populations and acceleration mechanisms, bringing us closer to quantifying their contribution to the observed galactic cosmic rays. Such clues may bring us substantially closer to solving the 100-year mystery of CR origins. We will review the SNRs detected thus far and discuss their properties, including as they relate to CR acceleration.

213.04D – **Gamma-ray Observations Of Star-forming Galaxies With The Fermi LAT**

Keith Bechtol[1], Fermi LAT Collaboration

[1]*Stanford / SLAC / KIPAC.*
10:30 AM - 10:50 AM

Recent detections of the starburst galaxies M82 and NGC 253 by gamma-ray telescopes suggest that galaxies rapidly forming massive stars are more luminous at gamma-ray energies compared to their quiescent relatives. Building upon those results, we examine a sample of 69 dwarf, spiral, and luminous and ultraluminous infrared galaxies using more than two years of data collected by the Large Area Telescope (LAT) on the Fermi Gamma-ray Space Telescope (Fermi). Measured fluxes from significantly detected sources and flux upper limits for the remaining galaxies in the sample are used to explore the physics of cosmic rays in star-forming galaxies. We confirm quasilinear scaling relations between both radio continuum luminosity and total infrared luminosity with gamma-ray luminosity which apply both to quiescent galaxies of the Local Group and low-redshift starburst galaxies. Using the relationship between infrared luminosity and gamma-ray luminosity, we estimate that unresolved star-forming galaxies at redshifts $0 < z < 2.5$ constitute 3-25% of the isotropic diffuse gamma-ray background intensity between 0.1-100 GeV.

213.05 – **Coasting External Shock in Wind Medium: An Origin for the X-ray Plateau Decay Component in Swift GRB Afterglows**

Rongfeng Shen[1], C. D. Matzner[1]

[1]*University of Toronto, Canada.*
10:50 AM - 11:00 AM

The plateaus observed in about one half of the early X-ray afterglows are the most puzzling feature in gamma-ray bursts (GRBs) detected by Swift. By analyzing the temporal and spectral indices of a large X-ray plateau sample, we find that 55% can be explained by external, forward shock synchrotron emission produced by a relativistic ejecta coasting in a $\rho \sim r^{-2}$, wind-like medium; no energy injection into the shock is needed. After the ejecta collects enough medium and transitions to the adiabatic, decelerating blastwave phase, it produces the post-plateau decay. For those bursts consistent with this model, we find an upper limit for the initial Lorentz factor of the ejecta, $\Gamma_0 \leq 46\ (\epsilon_e/0.1)^{-0.24}\ (\epsilon_B/0.01)^{0.17}$; the isotropic equivalent total ejecta energy is $E_{iso} \sim 10^{53}\ (\epsilon_e/0.1)^{-1.3}\ (\epsilon_B/0.01)^{-0.09}\ (t_b/10^4\ \mathrm{s})$ erg, where ϵ_e and ϵ_B are the fractions of the total energy at the shock downstream that are carried by electrons and the magnetic field, respectively, and t_b is the end of the plateau. Our finding supports Wolf-Rayet stars as the progenitor stars of some GRBs. It raises intriguing questions about the origin of an intermediate-Γ_0 ejecta, which we speculate is connected to the GRB jet emergence from its host star. For the remaining 45% of the sample, the post-plateau decline is too rapid to be explained in the coasting-in-wind model, and energy injection appears to be required.

213.06 – **Joint Swift/Fermi Observations Of Gamma-ray Bursts**

Eleonora Troja[1], on behalf of a larger collaboration

[1]*NASA/GSFC.*
11:00 AM - 11:10 AM

Combined Swift and Fermi observations, supported by other rapid response facilities, have propelled the study of GRB physics into an exciting new era. The synergy between Swift and Fermi offers an unprecedented broad band coverage of the afterglow spectral and temporal evolution since its early stages, opening a new window into the extreme physics of these powerful explosions. To date, only four bursts have been simultaneously detected by Swift and Fermi-LAT, each of them providing new clues into the origin of the observed GeV emission.

We summarize the current status of joint Swift/Fermi-LAT observations of GRBs, and discuss future perspectives.

213.07 – **Earth Occultation Monitoring of the Hard X-ray/Low-Energy Gamma Ray Sky with GBM**

Michael L. Cherry[1], A. Camero-Arranz[2], G. L. Case[1], V. Chaplin[3], M. H. Finger[4], P. A. Jenke[5], J. C. Rodi[1], C. A. Wilson-Hodge[5], GBM Earth Occultation team

[1]*Louisiana State Univ.,* [2]*Natl. Space and Technology Center,* [3]*Univ. of Alabama in Huntsville,* [4]*Universities Space Research Assoc.,* [5]*NASA Marshall Space Flight Center.*
11:10 AM - 11:20 AM

By utilizing the Earth occultation technique (EOT), the Gamma-Ray Burst Monitor (GBM) instrument aboard Fermi has been used to make nearly continuous full-sky observations in the 8-1000 keV energy range. The GBM EOT analysis program currently monitors an input catalog containing 235 sources. We will present the GBM catalog of sources observed in the first ~3 years of the EOT monitoring program, with special emphasis on the high energy (>100 keV) and time-variable sources, in particular the Crab, Cyg X-1, and A0535+26. We will also describe the initial results of an all-sky imaging analysis of the EOT data, with comparisons to the Swift, INTEGRAL, and Fermi LAT catalogs.

This work is supported by the NASA Fermi Guest Investigator program, NASA/Louisiana Board of Regents, and Spanish Ministerio de Ciencia de Innovacion.

213.08 – **A Statistical Approach to Recognizing Source Classes for Unassociated Sources in the Second Fermi-LAT Catalog.**

Maria Elena Monzani[1], N. Omodei[2], Fermi-LAT Collaboration

[1]*SLAC National Accelerator Laboratory,* [2]*Stanford University.*
11:20 AM - 11:30 AM

We have developed a new and innovative technique to classify Fermi sources based solely on their observed gamma-ray properties. Our technique, based on Classification Trees, uses the properties of known objects to build a classification analysis which provides the probability for an unidentified source to belong to a given astronomical class (Pulsar, AGN,...).

We have applied this technique to the second Fermi-LAT source catalog (2FGL), and computed a classification probability for each unidentified source. This provides a clearer picture of the unidentified source population and extends the number of interesting candidate objects, thus helping the community in scheduling multiwavelength observations.

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214 – First Science with LOFAR

Special Session – Room 12B – Tuesday, January 10, 2012, 10:00 AM - 11:30 AM

LOFAR, the Low Frequency Array, is a next generation radio telescope under construction in the north of the Netherlands and across Europe and a key pathfinder for the SKA. Utilizing a novel phased-array design, LOFAR is optimized for the largely unexplored low frequency range from 30-240 MHz. In the Netherlands, a total of 40 LOFAR stations are nearing completion with an initial 8 international stations currently being deployed in Germany, France, Sweden, and the UK. With its dense core array and interferometric baselines up to 1000 km, LOFAR has the potential to achieve unparalleled sensitivity (sub-mJy) and spatial resolution (sub-arcsecond) in the low frequency radio regime. In this session, we intend to present the community with an update on the status of the array and its current scientific capabilities as well as the upcoming opportunities for general, “open skies” observing. The session will also feature a number of short talks highlighting some initial science results obtained during the past year of commissioning and showcasing LOFAR’s scientific potential.

214.01 – **LOFAR: Current Status and Opportunities for Early Science**

Michael W. Wise[1]

[1]*ASTRON Netherlands Institute for Radio Astronomy.*
10:00 AM - 10:15 AM

LOFAR, the Low Frequency Array, is a new and innovative radio telescope designed to open up the relatively unexplored low frequency radio regime from 30-240 MHz to a broad range of astrophysical studies. As one of the first of a new generation of radio instruments, the International LOFAR Telescope (ILT) will provide a number of unique capabilities for the astronomical community. These include wide-field, high dynamic range imaging, high time resolution, dynamic real-time system response, buffered retrospective all-sky imaging and the ability to support multiple, simultaneous observing programs. LOFAR is moving steadily through its commissioning phase towards early science results and its first open international call for observing proposals. In this presentation, I will give an overview of the current status of the array as well as its current and planned scientific capabilities. I will summarize the ongoing commissioning process and conclude with a discussion of the upcoming Announcement of Opportunity for observing proposals in early 2012.

214.02 – **The LOFAR Multifrequency Snapshot Sky Survey (MSSS): Description and First Results**

George H. Heald[1], G. de Bruyn[1], R. Nijboer[1], M. Wise[1], R. Pizzo[1], LOFAR Collaboration

[1]*ASTRON, Netherlands.*
10:15 AM - 10:30 AM

One of the primary scientific applications of LOFAR is to produce high-quality images of large areas of the low-frequency radio sky. Much of the required data processing will be performed in an automated fashion. The calibration of LOFAR imaging data will strongly benefit from an initial broadband northern sky catalog. Producing this catalog is the primary goal of the LOFAR Multifrequency Snapshot Sky Survey (MSSS) that is planned to begin in the autumn of 2011. Within the range between 30 and 180 MHz, MSSS will probe the low-frequency sky at a sensitivity of order 10 mJy/beam, and angular resolution of 1-2 arcmin or better. It will thus dramatically expand the frequency range sampled in high-resolution radio surveys, and, crucially, provide spectral information about the detected sources. Using LOFAR’s unique multi-beaming mode, the survey will only require a rather modest investment in observing time. In this contribution, I will motivate and describe the survey design, including an overview of aspects that provide additional value beyond the development of the MSSS catalog itself. I will also present a status update, and demonstrate early results from the survey.

214.03 – **First Results on Galaxy Clusters with LOFAR**

Chiara Ferrari[1]

[1]*Observatoire de la Côte D'Azur, France.*
10:30 AM - 10:45 AM

Deep radio observations of galaxy clusters have revealed the existence of diffuse radio sources related to the presence of relativistic electrons and weak magnetic fields in the intracluster volume. The role played by this non-thermal intracluster component on the thermodynamical evolution of galaxy clusters and on their mass estimate is debated, with important implications for cosmological and astrophysical studies of the largest gravitationally bound structures of the Universe.

The low surface brightness and steep power-law spectra of diffuse cluster radio sources make them more easily detectable at low-frequencies. LOFAR is the first instrument able to detect diffuse radio emission in hundreds of massive galaxy clusters up to their formation epoch ($z \sim 1$). We present the first observations of clusters imaged by LOFAR and the huge perspectives opened by this instrument for non-thermal cluster studies.

214.04 – **Pulsars and Fast Transients: Charting the Low-Frequency Radio Sky at High Time Resolution with LOFAR**

Jason Hessels[1]

[1]*ASTRON, Netherlands.*
10:45 AM - 11:00 AM

The LOw Frequency ARray (LOFAR) is a radio interferometric telescope that promises to open a largely unexplored window on transient sources in the "radio sky", from timescales of nanoseconds to years. An important aspect of this will be the study of radio-emitting neutron stars in their various incarnations: slow pulsars, young pulsars, millisecond pulsars, magnetars, rotating radio transients, intermittent pulsars, et cetera. Pulsars and their brethren are the prototype of the more general "fast transients": sub-second, dispersed radio bursts which point the way to extreme, and potentially still unknown phenomena. For instance, prompt radio bursts from supernovae and other extra-galactic bursts have been hypothesized; these could prove to be powerful cosmological probes. I will discuss LOFAR's impressive ability to observe pulsars and to greatly enlarge the discovery space for (even rare) fast transients. I will also present the latest pulsar observations made during LOFAR's commissioning period, as well as our first scientific results. These are demonstrating the power of observing techniques that will be crucial for the next generation of radio telescopes as well as the effort to better understand the dynamic nature of the Universe.

214.05 – **Lofar Deep Imaging And Prospects For Detecting The Eor**

A G. de Bruyn[1], LOFAR EoR Key Science Project Team

[1]*Groningen/ASTRON, Netherlands.*
11:00 AM - 11:15 AM

One of the most exciting projects to be undertaken with LOFAR is the search for redshifted 21cm signals from the Epoch of Reionization (EoR). It is also one of the most challenging and difficult radio projects ever undertaken. Hundreds of hours of integration, in the band between 115 and 190 MHz, corresponding to HI redshifts between 6.5 and 11.5, will be needed to detect the feeble signals, many orders of magnitude below the signals generated by extragalactic discrete sources and the disk and halo of our Galaxy. In the spring of 2011 we have used the LOFAR telescope to conduct extensive commissioning observations with a still incomplete LOFAR towards two ’EoR-windows’. These observations were used to test the various RFI-excision, calibration and imaging algorithms and finetune the pipelines that will be used for the dataprocessing. A dedicated CPU/GPU cluster at the University of Groningen is used for that purpose.

The two windows are located at the North Celestial Pole and on the bright compact quasar 3C196 in a cool area of the Galactic halo. Typical LOFAR observations last 6 hours and are conducted completely at night. New observations, with an improved LOFAR, will commence in the Autumn of 2011.

Thusfar we have achieved the deepest low frequency images ever recorded; current noise levels are well below 1 mJy and the image dynamic range exceeds 200,000:1. We will briefly discuss the science goals of the LOFAR EoR project, our near term and longer term plans, and present results from the Spring and Autumn observations. We will also discuss the adopted calibration and processing strategy and how we plan to correct for effects due to ionospheric non-isoplanaticity and sidelobe confusion.

214.06 – **Radio Detection of Cosmic Particles with LOFAR**

Heino Falcke[1]

[1]*MPI Für Radioastronomie/Radboud University/ASTRON, Germany.*
11:15 AM - 11:30 AM

Ultra-high energy cosmic rays (UHECRs) have been detected up to energies around 10^20 eV, but their nature is still debated. Once an UHECR hits the Earth atmosphere, a shower of secondary particles is created, rushes though the geomagnetic field, and produces a bright radio flash for some tens of nanoseconds. The LOPES (LOFAR Prototype Station) already detected this emission and showed that radio is a good tracer of particle energy. Models of the emission suggest that radio is also a potentially good tracer of particle composition. As a consequence, the new LOFAR radio telescope has UHECRs detection built in: All ~2500 individual antenna elements in LOFAR come with a memory ring buffer (Transient Buffer Board, TBB) and real-time pulse detections, allowing particles above 10^17 eV to be detected. Moreover, a small particle detector array, LORA (LOFAR-Radboud Airshower array), provides cross-calibration and external triggers when desired. Using first commissioning data, the radio emission of UHECRs has been detected with exquisite detail, providing new insight into the emission process. The TBBs can also be used to search for sub-second astrophysical transients such as giant pulses from pulsars, stellar and planetary flares, cosmic ray impacts on the moon, and other exotic events.

215 – Cannon Prize: Weak Lensing - Revealing the Dark Side of the Universe

Invited Session – Ballroom D – Tuesday, January 10, 2012, 11:40 AM - 12:30 PM

215.01 – **Cannon Prize: Weak lensing - Revealing the Dark Side of the Universe**

Rachel Mandelbaum[1]

[1]*Carnegie Mellon University and Princeton University.*
11:40 AM - 12:30 PM

Weak gravitational lensing, the deflection of light from distant galaxies due to all intervening mass along the line of sight, is one of the most direct ways to observe dark matter. As a result, in the past decade, weak lensing has become a very important tool both for constraining cosmological parameters and for revealing the connection between galaxies and dark matter. I will begin by reviewing some of the most significant recent observational advances that were made possible by weak lensing. Next, I will outline some of the challenges and opportunities facing the lensing community in existing and upcoming imaging surveys. I will conclude with some perspective on how these challenges will be addressed to do ground-breaking work in the fields of cosmology, galaxy formation, and galaxy cluster formation and evolution with weak lensing observations in the next decade.

216 – Gemini Town Hall

Town Hall – Ballroom F – Tuesday, January 10, 2012, 12:45 PM - 1:45 PM

Staff from Gemini Observatory will meet with the community to report on progress and to discuss plans for future instrumentation and operations developments. Community desires for new instrument capabilities are a key issue, as a new generation of Gemini instruments is being defined now.

217 – Pulsars, Neutron Stars

Oral Session – Ballroom E – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

217.01 – **Millihertz Oscillations And Thermonuclear Bursts From Terzan 5: A Showcase Of Burning Regimes**

Manuel Linares[1], D. Altamirano[2], D. Chakrabarty[1], A. Cumming[3], L. Keek[4]

[1]*MIT,* [2]*University of Amsterdam, Netherlands,* [3]*McGill University, Canada,* [4]*University of Minnesota.*
2:00 PM - 2:10 PM

Different nuclear burning regimes are predicted on accreting neutron stars (NSs) depending mainly -but not only- on the amount of mass accreted on the NS per unit time and area. We present X-ray observations of a rapidly accreting 11 Hz pulsar in the globular cluster Terzan 5 that reveal four distinct thermonuclear bursting regimes. In one of them we find a steep (inverse cubic) relation between burst recurrence time and inferred mass accretion rate. We also report the discovery and detailed analysis of mHz quasi-periodic oscillations (QPOs) from the same NS, usually interpreted as marginally stable burning. We compare the unique burst and mHz QPO properties of this system to previous observations and to models of burst ignition near the helium burning stability boundary, and find new constraints on the heat sources present in the NS envelope. Finally, we discuss the potential impact of the NS magnetic field and spin on the expected burning regimes in the context of this particular system, which bridges the gap between accreting NSs in high- and low-mass X-ray binaries.

217.02 – **Quantitative and Qualitative Models in Support of the Supraluminal Model of Pulsar Emission**

John Singleton[1], A. Schmidt[2], J. Middleditch[3], H. Ardavan[4], A. Ardavan[5]

[1]*National High Magnetic Field Laboratory,* [2]*UNM/LANL,* [3]*LANL,* [4]*University of Cambridge, United Kingdom,* [5]*University of Oxford, United Kingdom.*
2:10 PM - 2:20 PM

Maxwell's equations establish that patterns of electric charges and currents can be animated to travel faster than the speed of light in vacuo, and that these supraluminal distribution patterns emit tightly focused packets of electromagnetic radiation that are fundamentally different from the emissions by previously known terrestrial radiation sources. Since a pattern of electric polarization is not bound to charged particles (though effected by them), it can be made to move faster than light. Recent theoretical work, data gathered from ground-based astrophysics experiments, and the analysis of pulsar observational data all strongly suggest supraluminal polarization currents whose distribution pattern follows a circular orbit as the mechanism of pulsar radiation. Here we present numerical calculations of the radiation field generated by a localized charge - as well as ``bunches" of such charges - in supraluminal rotation and compare our studies to astronomical observations of rapidly spinning, highly magnetized stellar remnants. We find that the radiated field has the following intrinsic characteristics: (i) it is sharply focused along a rigidly rotating spiral-shaped beam, (ii) it consists of either one or three concurrent polarization modes (depending on the relative position of the observer) that constitute contributions to the field from differing retarded times, (iii) it is highly elliptically polarized, (iv) the position angles of each of its linearly polarized modes swings across the beam by as much as 180 degrees, and (v) the position angles of two of its modes remain approximately orthogonal throughout their excursion across the beam. Our findings show that virtually all of the enigmatic features of pulsar radiation - the polarization properties, image structure and apparent radiation temperature as well as peak spectral frequencies - can be explained using a single, elegant model with few input parameters and no external assumptions.

217.03 – **Extreme Particle Acceleration via Magnetic Reconnection in the Crab Nebula**

Benoit Cerutti[1], D. A. Uzdensky[1], M. C. Begelman[1]

[1]*University of Colorado.*
2:20 PM - 2:30 PM

The discovery by Agile and Fermi of intense day-long synchrotron gamma-ray flares above 100 MeV in the Crab Nebula challenges classical models of pulsar wind nebulae and particle acceleration. We argue that the flares are powered by magnetic reconnection in the nebula. Using relativistic test-particle simulations, we show that particles are naturally focused into a thin fan beam, deep inside the reconnection layer where the magnetic field is small. The particles then suffer less from synchrotron losses and pile up at the maximum energy given by the electric potential drop in the layer. Applying this model to the Crab Nebula, we find that the emerging synchrotron emission spectrum above 100 MeV is consistent with the September 2010 flare observations. No detectable emission is expected at other wavelengths. This scenario provides a viable explanation for the Crab Nebula gamma-ray flares.

217.04 – **Constraints on the Emission Geometry of the "B" Pulsar in the Double Pulsar System**

Benetge B. Perera[1], M. A. McLaughlin[1], K. N. Gourgouliatos[2], M. Lyutikov[2], D. Lomiashvili[2], M. Kramer[3], I. H. Stairs[4], R. D. Ferdman[5], P. C. C. Freire[6], A. Possenti[7], R. P. Breton[8], R. N. Manchester[9], M. Burgay[7], A. G. Lyne[3], F. Camilo[10]

[1]*West Virginia University,* [2]*Purdue University,* [3]*University of Manchester, Jodrell Bank Observatory, United Kingdom,* [4]*University of British Columbia, Canada,* [5]*Jodrell Bank Center for Astrophysics, United Kingdom,* [6]*NAIC, Arecibo Observatory,* [7]*INAF-Osservatorio Astronomica di Cagliari, Italy,* [8]*University of Toronto, Canada,* [9]*Australia Telescope National Facility, Australia,* [10]*Columbia University.*
2:30 PM - 2:40 PM

We present the evolution of the radio emission from the 2.8 sec pulsar of the double

pulsar system J0737-3039A/B. The pulse profiles and the mean flux densities of pulsar B change significantly over five years of observation, culminating in the radio emission disappearance in 2008 March. Over this time, the flux density decreases by 0.177 mJy/yr at the brightest orbital phases and the pulse profile evolves from a single to a double peak, with a separation rate of 2.6 deg/yr. The pulse profile changes are most likely caused by relativistic spin precession and can be explained with an elliptical hollow-cone beam. This particular beam model constrains the geometrical parameters of the pulsar to be consistent with those derived in Breton et al. 2008. The magnetosphere of pulsar B is distorted by the strong stellar wind produced from pulsar A. The influence of these distortions on the orbital-dependent emission properties of pulsar B can be used to determine the location of the coherent radio emission generation region in the pulsar magnetosphere. Using a model of the wind-distorted magnetosphere of pulsar B and the well defined geometrical parameters of the system, we determine the minimum emission height to be 20 neutron star radii in the two bright orbital longitude regions. We can determine the maximum emission height by accounting for the amount of deflection of the polar field line with respect to the magnetic axis. This is estimated to be 2500 neutron star radii. The minimum and maximum emission heights we calculate are consistent with those estimated for normal isolated pulsars.

217.05 – **Multi-wavelength Observations of PSR J2222-0137**

Jason Boyles[1]

[1]*West Virginia University.*

2:40 PM - 2:50 PM

PSR J2222-0137 is a 32.8 ms, partially recycled binary pulsar that was discovered in the GBT 350-MHz drift-scan pulsar survey. With an orbital period of 2.4 days and a projected semi-major axis of 10.8 lt-s,

the companion is at least 1.1 solar masses for a canonical mass pulsar. A distance of

312 pc can be estimated from the dispersion measure of 3.27 pc cm^{-3} and makes this system the second closest pulsar binary system. The close proximity of PSR J2222-0137 has allowed us to conduct observations in the optical to search for its companion and X-ray to look for thermal emission while using VLBA to measure a parallax to this source. The precision timing obtained from PSR J2222-0137 has provide a mass measurement for the companion via the Shapiro delay and in turn for the pulsar also. Here we present the results of these observations and describe the properties of this system.

217.06 – **Statistical Analysis Of The Pulsars In The Parkes Multibeam Survey Reveals Evidence For Violation Of The Inverse-square Law**

Andrea C. Schmidt[1], J. Singleton[2], J. Middleditch[3], H. Ardavan[4], A. Ardavan[5]

[1]*LANL/UNM,* [2]*National High Magnetic Field Laboratory,* [3]*LANL,* [4]*University of Cambridge, United Kingdom,* [5]*University of Oxford, United Kingdom.*

2:50 PM - 3:00 PM

Recent theoretical work and data gathered from ground-based astrophysics experiments have shown unambiguously that all features of pulsar emission can be explained in terms of supraluminal (faster than light in vacuum) polarization currents whose distribution pattern follows a circular orbit. Using the supraluminal model of pulsar emission, it was possible to explain quantitatively several observables from the Crab pulsar, including the spacing and the widths of the emission bands at frequencies around 8 GHz, the maximum of the radiation spectrum, and the overall continuum spectrum across 16 orders of magnitude in frequency. Subsequently, successful quantitative fits were carried out for 8 other pulsars and a related supraluminal model reproduced the general form of pulsar Stokes parameters. Here, we demonstrate a further prediction for rotating supraluminal sources; that there is a component of the pulsar's flux that decays as 1/distance, rather than as the conventional inverse square law. To this end we will employ a Maximum Likelihood Method (MLM) analysis of observational data from 971 pulsars in the Parkes Multibeam Survey. The MLM, derived from a widely accepted approach originally used by George Efstathiou to study the red shifts of very distant objects, is carried out to circumvent the significant Malmquist bias due to the increasing non-detection of weaker pulsars. We will then apply the results of this analysis to Supernova 1987A and show how our model can account for the fine details of its bipolarity, ``Mystery Spot'', and early light curve, as well as for the apparent anomalous dimming with distance of many Type Ia SNe in general, thereby questioning their usefulness as "standard candles" in cosmological interpretation.

217.07 – **Probing Gamma-ray Pulsar Emission with Light Curve Modeling and Phase-Resolved Spectroscopy**

Megan E. DeCesar[1], A. Harding[2], M. C. Miller[1], Y. Contopoulos[3], C. Kalapotharakos[3], D. Parent[4]

[1]*University of Maryland,* [2]*NASA Goddard Space Flight Center,* [3]*Academy of Athens, Greece,* [4]*Naval Research Lab.*

3:00 PM - 3:10 PM

The high-quality Fermi LAT observations of gamma-ray pulsars have opened a new window to understanding the generation mechanisms of high-energy emission from these systems. The high statistics allow for careful modeling of the light curve features as well as for phase-resolved spectral modeling. We model the LAT light curves of a subset of bright LAT pulsars using simulated high-energy light curves. The model light curves and phase-dependent radii of curvature are generated using geometrical representations of the outer gap and slot gap/two-pole caustic emission models, within the context of both the vacuum retarded dipole and force-free magnetosphere models. These simulated light curves are compared with observed LAT light curves via maximum likelihood using the Markov Chain Monte Carlo method to explore the phase space of fitted parameters such as magnetic inclination, viewing angle, maximum emission radius and gap width. We find that the observed light curves are better fit with the vacuum dipole magnetic field structure, as the force-free magnetosphere produces phase lags between the gamma-ray and radio peaks larger than those observed. We have also used the measured phase-dependent spectral cutoff energies to estimate the accelerating parallel electric field dependence on radius for each pulsar, under the assumptions that the high-energy emission is dominated by curvature radiation and the geometry (radius of emission and minimum radius of curvature of the magnetic field lines) is determined by the best fitting light curves for each model.

217.08 – **Spectral Trends in the Second Fermi LAT Catalog of Gamma-ray Pulsars**

Ozlem Celik[1], Fermi LAT Collaboration, Pulsar Timing Consortium

[1]*NASA Goddard Space Flight Center.*

3:10 PM - 3:20 PM

The Fermi Large Area Telescope (LAT) detected almost 100 pulsars in gamma-rays using the sky-survey data collected in the first three years of its observations. These pulsars equally populate three different sub-classes: young radio-quiet and radio-loud pulsars, and millisecond pulsars. The second Fermi LAT catalog of gamma-ray pulsars will summarize the light curve and spectral characteristics of these pulsars and study their gamma-ray properties as a population to search for trends and differences between different classes with a prospect of improving our understanding of high-energy pulsed emission. We will report some of these results, focusing on the observed spectral properties and trends.

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218 – The Rossi X-ray Timing Explorer: Taking the Pulse of the Universe

Special Session – Room 17B – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

Over the course of its 16 year mission, NASA's Rossi X-ray TimingExplorer (RXTE) has revolutionized our view of the X-ray sky. With apowerful and unique combination of large collecting area, broad-bandspectral coverage, high time resolution and highly flexiblescheduling, RXTE observations have led to breakthroughs in ourphysical understanding of the extreme environments of accretingcompact objects, including neutron stars and Galactic andextragalactic black holes. Among these breakthroughs were thediscoveries of the kilohertz quasiperiodic oscillations of accretingneutron stars and black holes (the fastest periodic signals known inastronomy), as well as the finding of the first accreting millisecondX-ray pulsars, that solidified the link between recycled millisecondradio pulsars and their accreting progenitors.

In this special session we will provide a survey of the amazingly richobservational legacy of RXTE, with a focus on recent discoveries,ongoing research, and the multi-wavelength perspective that RXTEcoordinated observations have helped reveal. We will also highlightand discuss the frontier scientific questions that RXTE observationshave helped to bring into focus, but that only future, more sensitiveX-ray timing missions will be able to fully exploit.

218.01 – **RXTE's Contributions to Our Understanding of Neutron Stars**

Frederick K. Lamb[1]

[1]*Univ. of Illinois.*

2:00 PM - 2:17 PM

Discoveries made using RXTE's unique capabilities produced a revolution in our understanding of neutron stars, a revolution that has had a broad impact on astronomy. The discovery of accreting neutron stars with millisecond spin periods demonstrated the long-sought evolutionary link between neutron stars in low-mass X-ray binary systems and the millisecond rotation-powered pulsars and has

led to a much better understanding of the evolution of neutron star masses, magnetic fields, and spin rates, and the prospects for detecting gravitational radiation from neutron stars. High-time-resolution studies of thermonuclear X-ray bursts and the discovery of millisecond burst oscillations have revolutionized our understanding of the nuclear and radiation physics of these bursts, confirmed that there is a limit to the spin-up of neutron stars by accretion torques, and created new possibilities for determining their masses and radii. The discovery of accretion-powered kilohertz oscillations -- the fastest variability known in all of astronomy -- has provided a new probe of strong-field general relativity and new constraints on the properties of accretion disks and neutron stars. In addition to these major discoveries, RXTE has enabled a wealth of other discoveries and advances, including the demonstration that soft gamma-ray repeaters and anomalous X-ray pulsars are neutron stars with similar properties, the development of improved models of accretion disks and binary star evolution, and a better understanding of the interaction of disks and magnetospheres and the formation of relativistic jets. In addition to resolving many fundamental questions, discoveries made using RXTE have raised important new questions, making clear the need for a follow-on mission with enhanced timing capabilities. This research was supported by NSF grant AST0709015 and the Fortner Endowed Chair at the University of Illinois.

218.02 – **Anomalous X-ray Pulsars and Soft Gamma Repeaters as Magnetars: The RXTE Legacy**

Victoria M. Kaspi[1]

[1]*McGill Univ., Canada.*

2:20 PM - 2:37 PM

Prior to the launch of RXTE, the hypothesis by Thompson and Duncan that there exists a class of ultra-highly magnetized young neutron stars whose emission is powered by the decay of their magnetic field -- the so-called `magnetar' model -- was beautiful, yet unproven. The magnetar model was motivated the existence of Soft Gamma Repeaters (SGRs), which had been observed to exhibit dramatic X-ray and soft gamma ray bursts and in one case, 8-s pulsations in the tail of a major flare. Meanwhile, there was recognized another puzzling group of seemingly very different objects, the 'Anomalous X-ray Pulsars' (AXPs), so-called due to their bright, several-second X-ray pulsations, steady spin down, low spin-down power and absence of any binary companion from which mass could be accreted. AXPs had also been suggested to be magnetars by Thompson and Duncan, though this too was unproven.

Today, thanks to multiple landmark RXTE results, these two groups of object have been united into a single source class, which is now nearly universally identified with magnetars. Specifically, the discovery from SGRs of regular X-ray pulsations and steady spin-down (as had been observed in AXPs), as well as the discovery of bright X-ray bursts from AXPs (as had been observed in SGRs) has demonstrated unambiguously the common nature of AXPs and SGRs, as was predicted uniquely in the magnetar model. Moreover, RXTE discoveries of several observational links between AXPs, SGRs and rotation-powered pulsars, specifically the detection of spin-up glitches in AXPs, as well as the observation of a temporary metamorphosis of one rotation-powered pulsar into a magnetar-like source, hint at a broader unification of the magnetars with the general radio pulsar population, with the observational differences attributable to a combination of age and magnetic field.

218.03 – **Black Holes with RXTE: New Insights**

John Tomsick[1]

[1]*UC Berkeley/SSL.*

2:40 PM - 2:47 PM

Over the past 15 years, the Rossi X-ray Timing Explorer has been a remarkable machine for the study of accreting stellar mass black holes. Due to the variable and often transient nature of these systems across the 2-200 keV bandpass, these studies have utilized the full range of RXTE capabilities, including using ASM for finding new black hole systems or outbursts, PCA and HEXTE for broadband spectral studies, and the unprecedented timing capabilities of PCA (in terms of time resolution and collecting area) that have opened up a new window for understanding accreting black holes. RXTE has enabled fundamental advances by constraining black hole spins and probing the inner regions of the accretion disk as well as making critical contributions to studies of powerful outflows in the form of jets. In this talk, I will present a selection of results obtained throughout the mission that demonstrate the advances that have been possible because of RXTE. The results include discoveries of previously unknown high-frequency signals that are fundamental to our understanding of accreting black holes, following the detailed evolution of multi-wavelength properties that constrain the disk/jet connection, and the correlations and patterns that have emerged due to the huge amount of data from observations of black holes by RXTE. These results have only been possible because of the efforts of the large community of observers, theorists, mission scientists, mission planners, and instrumentalists, and it has been a great pleasure to work with the RXTE community during the mission.

218.04 – **RXTE Observations of Active Galactic Nuclei: The Power of Well-Sampled Light Curves**

Alan P. Marscher[1]

[1]*Boston Univ.*

2:50 PM - 3:07 PM

The richly detailed X-ray light curves provided by RXTE, in concert with other telescopes, has greatly enhanced our understanding of high-energy phenomena in the relativistic jets and accretion disk/corona systems of active galactic nuclei. The power spectra of the variations in both the X-ray and optical flux of Seyferts and radio galaxies show similarities to those of black-hole X-ray binary systems in their intermediate-soft states, with time-scales proportional to the mass of the black hole. Minima in the the X-ray light curves of the radio galaxies 3C 111 and 3C 120 coincide with ejections of superluminal knots seen in the radio jets, revealing a strong accretion disk-jet connection. A time delay of 2-3 months between an X-ray dip and passage of the associated knot through the bright, stationary feature at the upstream end of the jet on mm-wave VLBA images (the "core") indicates that the core lies 0.5-1 pc from the black hole.

In blazars, comparison of X-ray light curves with those at other wavebands reveals considerable complexity, with times of both strong and weak (or non-existent) correlations. Some flares are essentially simultaneous across wavebands (including GeV gamma rays observed by the Fermi LAT) and others show significant time delays. The X-ray emission, once thought to be either synchrotron radiation or synchrotron self-Compton scattering, often agrees better with the expectations of inverse Compton scattering of photons originating from outside the jet.

The author's research reported in the presentation has been supported by numerous NASA grants, as well as NSF grant AST-0907893.

218.05 – **Future Opportunities for X-ray Timing After RXTE**

Deepto Chakrabarty[1]

[1]*MIT.*

3:10 PM - 3:27 PM

Over its 15 year lifetime, RXTE's combination of large area, wide bandpass, timing sensitivity, and flexible scheduling has led to the discovery of a number of important new phenomena in neutron stars and black holes. A more sensitive future mission could potentially employ some of these phenomena to probe fundamental questions in the astrophysics of compact objects. Examples include pulse shape modeling to measure neutron star radii, using oscillations during giant magnetar bursts to probe the internal structure of neutron stars, and linking the frequency structure of high-frequency quasi-periodic oscillations (QPOs) to the fundamental parameters of neutron stars and black holes I will review such science topics and summarize future missions and mission concepts that will follow up the science contributions of RXTE. These include the soon-to-be launched Indian ASTROSAT mission, the LOFT M-class and ATHENA L-class mission concepts currently under study by ESA, and the AXTAR and NICE concepts under development as future U.S. Explorer mission concepts.

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219 – The BigBOSS Multi-Object Spectrograph on the Mayall Telescope

Special Session – Room 16B – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

BigBOSS is a 3-degree field, 5000-fiber optical spectrographproposed for the prime focus of the Mayall 4-m telescope. It is designedto undertake an unprecedented redshift survey of 20 million galaxies andQSOs to measure the gravitational growth of structure and the effects ofdark energy from z=3 to z=0.5. In addition, BigBOSS will be a facilityinstrument, available for use by the astronomical community.

This session will review the capabilities of the BigBOSS instrument,the impact of the key project, and the opportunities for community science.

219.01 – **An Overview of the BigBOSS Project**

Arjun Dey[1]

[1]*NOAO.*

2:00 PM - 2:15 PM

The BigBOSS Collaboration aims to build a highly-multiplexed (5000 fiber), moderate-resolution (R~3000-5000), wide-field (3 degree diameter) spectroscopic capability for the Mayall 4m telescope at the Kitt Peak National Observatory. The instrument will be used to undertake a large galaxy redshift survey with the primary goal of measuring the baryon acoustic oscillation scale and thereby constraining the dark energy equation of state. The instrument will be a facility instrument at the Mayall and will be available for public use through NOAO. This talk will briefly describe the instrument capabilities and

goals and the current state of the project.

219.02 – **The BigBOSS Instrument**

Natalie Roe[1]

[1]*Lawrence Berkeley National Lab.*
2:15 PM - 2:30 PM

I will give an overview of the proposed BigBOSS instrument, to be installed at the Mayall 4m telescope at Kitt Peak National Observatory. The BigBOSS instrument includes an optical corrector to provide a 3 degree diameter field of view, a focal plane with 5000 robotically actuated fibers, and 10 identical moderate resolution 3-arm spectrographs.

219.03 – **Cosmology With the BigBOSS Survey**

Nikhil Padmanabhan[1], BigBOSS collaboration

[1]*Yale U..*
2:30 PM - 2:45 PM

The BigBOSS survey aims to map an unprecedented volume of the Universe, covering 14000 sq.deg. and redshifts to z=3. These measurements will precisely constrain the expansion and linear growth

rate of the Universe through the baryon acoustic oscillation (BAO) and redshift space distortion (RSD) methods. We present the latest predictions of these measurements, and discuss their ability to constrain dark energy properties, both by themselves and in combination with existing and planned measurements. In addition to the dark energy science, BigBOSS will strongly constrain other cosmological parameters like the neutrino mass and the spectrum of initial density perturbations, as well as test for deviations from our standard model like non-Gaussianities in the initial conditions. We summarize the constraints achievable by BigBOSS

and improvements over current surveys.

219.04 – **Extragalactic Science with BigBOSS**

Martin White[1]

[1]*UC Berkeley.*
2:45 PM - 3:00 PM

The BigBOSS collaboration will cary out the largest spectroscopic survey of the Universe to date, producing a data set which will have an unprecedented impact on a wide range of science. In this talk I will give exemplars of the sorts of advances one could expect from BigBOSS in the area of extragalactic astronomy.

219.05 – **Mapping the Milky Way Galaxy with BigBOSS**

Constance M. Rockosi[1]

[1]*UCO/Lick Observatory.*
3:00 PM - 3:15 PM

The wide field, high multiplex and flexibility of the BigBOSS instrument on the 4 m Mayall telescope will make it a powerful instrument for investigations of our Galaxy and its nearby neighbors. Observing programs using BigBOSS will be able to map the halo, disk and bulge our Galaxy with large samples and over wide areas, enabling studies of the stellar populations, kinematics and spatial distribution of stars throughout the Galaxy. The wide field and sensitivity are well matched to investigations of the Milky Way satellites and out to M31. I will describe some example science programs and observing modes that highlight the planned capabilities of the BigBOSS instrument for Milky Way and Local Group science.

219.06 – **BigBOSS Community Workshop at NOAO**

Catherine A. Pilachowski[1]

[1]*Indiana University.*
3:15 PM - 3:30 PM

A community workshop to explore the broad astrophysical

impact of the proposed BigBOSS wide-field, multi-object spectrograph on the Mayall 4-m telescope was held at NOAO in September, 2011. The workshop provided opportunities for the astronomical community to learn about the capabilities of the BigBOSS instrument, to share aspirations for the science to be done with BigBOSS, and to impact the prioritization and preservation of instrument capabilities, observing modes and data pipeline deliverables. Following reviews of the proposed instrument capabilities, user modes, and data products, break-out sessions provided an opportunity for participants to focus on innovative scientific applications to extragalactic, Galactic, and Solar System research, and to identify key observing modes and pipeline requirements needed for community science. Here, we report on the conclusions and recommendations of the *NOAO BigBoss Community Workshop*.

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220 – Star Formation II

Oral Session – Room 12A – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

220.01 – **Observing Turbulent Fragmentation In Simulations: Through the Looking Glass of CARMA and ALMA**

Stella Offner[1], J. Capodilupo[2], S. Schnee[3], A. Goodman[1]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Harvard University,* [3]*National Radio Astronomy Observatory.*
2:00 PM - 2:10 PM

We use the CASA software package to synthetically observe binaries forming as a result of turbulent fragmentation in a radiation-hydrodynamic simulation of a collapsing molecular cloud. By following the evolution of such pairs beginning in the prestellar core stage, we are able to make predictions about the feasibility of observing such fragmentation using the Combined Array for Research in Millimeter-wave Astronomy (CARMA) and the Atacama Large Millimeter/submillimeter Array (ALMA). We find that while intermediate ALMA configurations may potentially resolve structure with one fourth the integration time of CARMA, both instruments only marginally resolve sub-structure within ~25 kyr of the onset of gravitational collapse. In addition, interferometric spatial filtering significantly reduces traces of filamentary gas morphology on < 0.1 pc scales. Thus, even with the improved sub-arcsecond resolution of ALMA, constraining stellar multiplicity at the earliest stages of star formation will be challenging.

220.02D – **Probing the Role of Magnetic Fields in Star Formation with BLAST-Pol**

Laura M. Fissel[1], BLAST-Pol Collaboration

[1]*University of Toronto, Canada.*
2:10 PM - 2:30 PM

Polarimetry is a powerful tool for studying the importance of magnetic fields in the star formation process. However, at present there are very few submm/mm polarimetry observations of large scale fields within molecular clouds. BLAST-Pol, the Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry, maps linearly polarized dust emission at 250, 350 and 500 microns; it has the unique combination of sensitivity to large scale magnetic fields, and arcminute resolution necessary to trace fields into prestellar cores and dense filaments. In this presentation I will give a brief overview of the instrument, its performance during the first BLAST-Pol science flight completed in January 2011, and plans for future flights. I will also show preliminary maps from the first science flight and explain how these maps will be used to study the relationship between large and small scale magnetic fields in molecular clouds, the degree of order in the field, and the relationship between the magnetic field structure and the morphology of filaments and cores within the clouds.

The BLAST-Pol collaboration gratefully acknowledges the support of NASA, NSF Office of Polar Programs, the CSA (Canada), the STFC (UK), NSERC (Canada), and the Leverhulme Trust (UK).

220.03D – **What the Spatial Distribution of Stars tells us about Star Formation and Massive Cluster Formation**

Eli Bressert[1], N. Bastian[2], L. Testi[3], J. Patience[4], S. Longmore[3]

[1]*ESO/Univ. of Exeter/CfA, Germany,* [2]*Excellence Cluster Universe, Germany,* [3]*ESO, Germany,* [4]*University of Exeter, United Kingdom.*
2:30 PM - 2:50 PM

We present a dissertation study on two recent results regarding the clustering properties of young stars. First, we discuss a global study of young stellar object (YSO) surface densities in star forming regions based on a comprehensive collection of Spitzer Space Telescope surveys, which encompasses nearly all star formation in the solar neighbourhood. It is shown that the distribution of YSO surface densities is a smooth distribution, being adequately described by a lognormal function from a few to 10^3 YSOs pc^{-2}, with a peak at ~22 YSOs pc^{-2} and a dispersion of ~0.85. We find no evidence for multiple discrete modes of star-formation (e.g. clustered and distributed) and that not all stars form in clusters. A Herschel Space Observatory study confirms the YSO surface density results by observing and analyzing the prestellar core population in several star forming regions.

Secondly, we propose that bound stellar clusters primarily form from dense clouds having escape speeds greater than the sound speed in photo-ionized gas. A list of giant molecular clumps with masses $>10^3$ $M_\odot$ that have escape speeds greater than the sound speed in photo-ionized plasma is compiled from the Bolocam Galactic Plane Survey. In these clumps, radiative feedback in the form of gas ionization is bottled up, enabling star formation to proceed to sufficiently high efficiency so that the resulting star cluster remains bound even after gas removal. We present over ten candidates that will most likely form $>10^3$ $M_\odot$ star clusters and two of them that are comparable to NGC

3603 (>10^4 $M_\odot$). Thus, providing us with an outlook on the next generation of star clusters in the Milky Way and clues to the initial conditions of massive cluster formation.

220.04 – **The Progression Of Star Formation In The Rosette Molecular Cloud**

Jason E. Ybarra[1], C. Román-Zúñiga[2], J. Wang[3], E. D. Feigelson[4], Z. Balog[5], E. A. Lada[1]

[1]Univ. of Florida, [2]Universidad Nacional Autónoma de México, Mexico, [3]Harvard-Smithsonian Center for Astrophysics, [4]The Pennsylvania State University, [5]Max-Planck Institut für Astronomie, Germany.

2:50 PM - 3:00 PM

Using Spitzer Space Telescope and Chandra X-ray data, we identify YSOs in the Rosette Molecular Cloud (RMC). By being able to select cluster members and classify them into YSO types, we are able to track the progression of star formation locally within the cluster environments and globally within the cloud. We employ nearest neighbor method (NNM) analysis to explore the density structure of the clusters, gaussian mixture modeling to estimate cluster properties, and ratio mapping to study age progressions and age variations in the cloud and clusters. We will investigate whether star formation proceeds sequentially or simultaneously in the cloud.

This work is based in part on archival data obtained with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided by an award issued by JPL/Caltech and a NASA GSRP fellowship.

220.05 – **A Systematic Study of Deuteration of Dense Cores in Perseus**

Rachel Friesen[1], H. Kirk[2], Y. Shirley[3]

[1]National Radio Astronomy Observatory, [2]Harvard Smithsonian Center for Astrophysics, [3]University of Arizona.

3:00 PM - 3:10 PM

Because of the timescales involved in the physical collapse and chemical evolution of a star-forming molecular core, it has been proposed that the abundance of a molecule relative to its deuterated isotopologue can be used as a probe of the core age. I will present results from a pointed survey of N2D+ 3-2 and 2-1 emission towards 65 starless and protostellar cores within the Perseus molecular cloud, with the goal of characterizing those factors which impact the core chemistry, while excluding cloud-to-cloud variation. We find an average N2D+/N2H+ abundance ratio, or deuterium fractionation, for all cores of 0.009. While we find no difference between the deuterium fractionation of starless and protostellar core populations, cores found in more clustered regions have greater deuterium fractionation levels than those in more isolated environments. We additionally analysed the core deuterium fractionation against traditional probes of core evolution, including core temperature, density, and C18O depletion, but find no trends of significance. Our observations contradict previous predictions of using deuteration as a simple probe of age, and suggest that deuteration levels will need to be used with care to estimate core evolutionary states.

220.06 – **The Magnetic Field Surrounding Serp-FIR1**

Nicholas L. Chapman[1], J. A. Davidson[2], G. Novak[1], T. Matthews[1], B. Matthews[3], P. F. Goldsmith[4], N. Volgenau[5], J. Vaillancourt[6]

[1]Northwestern University/CIERA, [2]University of Western Australia, Australia, [3]Herzberg Institute, Canada, [4]Jet Propulsion Laboratory, [5]California Institute of Technology, [6]Universities Space Research Association, SOFIA.

3:10 PM - 3:20 PM

We present a 350 micron SHARP/CSO polarization map of the environment surrounding the intermediate-mass YSO Serp-FIR1. These observations are part of a larger program to test the magnetically regulated star formation model using a statistically significant sample of relatively isolated star-forming cores. This model predicts that the magnetic field in these cores will have an hourglass morphology and that the symmetry axis of the magnetic field will be aligned with the outflow axis. We will discuss the results of Serp-FIR1 in terms of this model and compare it to our previously published results. This work is funded by NSF grant AST-0909030.

220.07 – **Initial Conditions For Star Formation In Clusters: Physical And Kinematical Structure Of The Starless Core Opha-n6**

Tyler L. Bourke[1], P. Myers[1], P. Caselli[2], J. Di Francesco[3], A. Belloche[4], R. Plume[5], D. Wilner[1]

[1]Harvard-Smithsonian, CfA, [2]U.Leeds, United Kingdom, [3]Herzberg Institute of Astrophysics, Canada, [4]Max Planck Institut für Radioastronomie, Germany, [5]U.Calgary, Canada.

3:20 PM - 3:30 PM

We present high spatial (<300 AU) and spectral (0.07 km s^{-1}) resolution Submillimeter Array observations of the dense starless cluster core Oph A N6, in the 1 mm dust continuum and the 3-2 lines of N_2H^+ and N_2D^+. The dust continuum observations reveal a compact source not seen in single-dish observations, of size ~1000 AU and mass 0.005-0.01 M_{sun}. The line observations, combined with single-dish observations, reveal a core of size 3000 x 1400 AU elongated in a NW-SE direction, with almost no variation in either line width or line center velocity across the map, and very small non-thermal motions. The deuterium fraction has a peak value of ~0.15 and is >0.05 over much of the core. The N_2H^+ column density profile across the major axis of Oph A-N6 is well represented by an isothermal cylinder, with temperature 20 K, peak density 7.0 x 10^6 cm^{-3}, and N_2H^+ abundance 2.7 x 10^{-10}. The mass of Oph A-N6 is estimated to be 0.35 M_{sun}, compared to a value of 0.18 M_{sun} from the isothermal cylinder analysis, and 0.65 M_{sun} for the critical mass for fragmentation of an isothermal cylinder. Compared to isolated low-mass cores, Oph A-N6 shows similar narrow line widths and small velocity variation, with a deuterium fraction similar to "evolved" dense cores. It is significantly smaller than isolated cores, with larger peak column and volume density. The available evidence suggests that Oph A-N6 has formed through the fragmentation of the Oph A filament and is the precursor to a low-mass star. The dust continuum emission suggests that it may already have begun to form a star.

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221 – Working in Science Policy

Special Session – Ballroom G – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

The goal of the panel is to encourage intelligent and enthusiasticastronomers into the field of public policy. The panel will focus onhow to transition from a career in astronomy to a career in sciencepolicy and how to make communicating with policy makers a part of yourcareer.

Transitioning into the world of public policy from astronomy is aunique experience for eachindividual. There is no certain path one must take from your currentcareer to Capitol Hill. Each panelist will tell their story on howthey made the transition from astronomer to public policy and why theywere motivated to pursue this type of career. The panelist range inexperience, career stage, and method of transition to illustrate thedifferent ways to success. More scientists are entering a career inpublic policy, however the role of the public scientist communicatingwith policy makers is still very important.

Panelist include:Dr. Bethany Johns, the AAS Johns Bahcall Public Policy Fellow
Dr. Nicholas Suntzeff, Jefferson Senior Science Fellow & Humanitarian Affairs Officer
Dr. Carol Christian, Deputy of the Community Missions Office, Division of STScI
Celinda Marsh, Space Science Program Examiner at the Office of Management and Budget
Dr. Marcos Huerta, Special Assistant, Office of the Director, Office of Science at the Department of Energy

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222 – How to Build a Milky Way: A Blueprint From the SDSS-III SEGUE Survey II

Special Session – Room 18C – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

As studies of the Milky Way enter the era of large surveys, we are finding that the new detailed, multi-dimensional datasets, combined with powerful new simulations of galaxy formation and evolution in a cosmological context, are transforming our view of the Milky Way's history. SEGUE is the SDSS project focused on the formation and evolution of the Milky Way as traced by its stars.

The survey observations are now complete, and the data have been released to the public. They consists of 3240 square degrees of ugriz imaging at low Galactic latitude and 370,000 stellar spectra to g=20. We have made extensive checks of our pipeline stellar parameter values using ugriz photometry and spectroscopy of well-studied cluster and field stars. The combination of large sample size and depth has enabled SEGUE to address long-standing questions such as the disk metallicity distribution and gradients, as well as newer questions such as the role of radial migration in shaping the disk. We have traced halo structure and substructure with larger and deeper samples than ever before, including thousands of outer halo giants. The homogeneous nature of the survey data also enable illuminating tests of selection biases, historically the bane of galactic stellar populations studies.

222.01 – **Exploring the Stellar Halo of the Milky Way with the Sloan Digital Sky Survey and PanSTARRS1**

Eric F. Bell[1], C. T. Slater[1], J. Bailin[1], X. Xue[2], C. Ruhland[3], N. F. Martin[4], Pan-STARRS 1 consortium

[1]*University of Michigan,* [2]*Key Lab of Optical Astronomy, National Astronomical Observatories, Beijing, China,* [3]*University of Hertfordshire, United Kingdom,* [4]*Max-Planck-Institut fuer Astronomie, Germany.*

2:00 PM - 2:12 PM

The Lambda CDM paradigm predicts that the outer parts of galaxies should, in large part, consist of material tidally stripped off of smaller dwarf galaxies as they are incorporated into the potential of the larger galaxy. We present results from the exploration of the structure and stellar populations of the Milky Way stellar halo. To date, we have focused on understanding the structure of the stellar halo as probed by two key tracer stellar populations - main sequence turn-off stars (MSTO; a well-populated diagnostic of a wide range of stellar populations), and blue horizontal branch stars (BHB; a sparsely-sampled standard candle indicative of ancient metal-poor populations, but available to larger distances). We find that the stellar halo is richly substructured as traced by MSTO and BHB stars, in both 3D space and in velocity space. Furthermore, we find that the degree and type of substructure showed by both populations are different - the ratio of BHB to MSTO stars changes from place to place in the halo, with coherent values of BHB/MSTO star number in given clearly-recognizable structured (e.g., the Sagittarius stream, low-latitude stream, etc.) Where possible, we compare quantitatively with models of galaxy formation in a cosmological context. The quantitative predictions of such models do depend on the assumptions underlying the model, and we demonstrate in particular the importance of a disk potential in driving the character and structure of stellar halos in a cosmological context. We find a close quantitative correspondence between predictions of spatial and velocity substructure from the cosmologically-motivated models and the observations for both MSTO and BHB stars, giving weight to the notion that stellar halos, at least to first order, present an unparalleled opportunity to study the formation of individual galaxies in a cosmological context.

222.02 – **Measuring Substructure with SEGUE K Giants and BHB Stars**

Heather Morrison[1]

[1]*Case Western Reserve University.*

2:15 PM - 2:27 PM

New substructure measurements in the Milky Way halo will be presented, using the large samples of SEGUE K giants and BHB stars which stretch into the outer halo. We see interesting differences in substructure between inner and outer halo and between K stars and BHB stars, and report a new distant stream likely to be associated with the early disruption of the Sgr dwarf.

222.03 – **In Situ Measurement of the Metallicity Gradient in the Galactic Halo**

Paul Harding[1]

[1]*Case Western Reserve University.*

2:30 PM - 2:42 PM

The metallicity gradient in the Milky Way halo is a controversial topic: early studies such as that of Zinn (1985) found no gradient outside the solar radius, while the recent work of Carollo et al (2007), who used orbital properties of local halo stars to infer the metallicity of the outer halo, claims a strong negative gradient, with the outer halo significantly more metal poor than the local halo. This measurement is important for the constraints it will give us on the balance between in situ halo formation and accretion of halo stars, and also for constraints on the assembly history of the dark halo. I will discuss a large sample of in situ halo stars (K giants found by SEGUE) which stretches into the far outer halo, removing the necessity for extrapolating from local stars.

222.04 – **Characterizing Halo Substructure with Kapteyn Proper-Motion and with SDSS/SEGUE Data**

Dana Casetti[1]

[1]*Yale University.*

2:45 PM - 2:57 PM

The Kapteyn survey is aimed at obtaining 3D velocities for stars in streams and overdensities found in the halo from large-area photometric surveys. While our main focus are proper-motion determinations, we also obtain radial velocities from our own program as well as from SEGUE.

To date, this survey has provided most of the existing 3D kinematical data accurate enough to characterize such substructure, including modeling of Sagittarius's tidal trailing tail, velocities in the Anticenter/Monoceros structure and in the Virgo Stellar Stream.

Here we briefly describe the survey, show comparisons with existing deep proper-motion surveys and summarize recent results. Next, we focus on new results obtained in the Virgo Stellar Stream and in the Anticenter/Monoceros structure.

222.05 – **Dynamical Structure of the Galaxy From the Local Kinematics of M Subdwarfs**

Sebastien Lepine[1]

[1]*American Museum of Natural History.*

3:00 PM - 3:12 PM

A search of the SDSS and SEGUE spectroscopic databases has turned over 10,000 M subdwarfs, most locatd with a few hundred parsecs from the Sun. Kinematics of these low-mass, metal-poor stars were calculated from proper motions, spectroscopic distances, and radial velocity measurements. The distribution reveals that the moderately metal-poor subdwarfs (sdM) have motions consistent with the Galactic thick disk, but with some possibly associated with the Galactic halo. The kinematics of the more metal-poor extreme subdwarfs (esdM) and ultrasubdwarfs (usdM), on the other hand, unambiguously associates them with the halo population. M subdwarfs from both the inner and outer halo are identified, with the outer halo objects displaying significantly lower mean metallicities. While the distribution does not support the existence of local halo substructure (streams), the outer halo subdwarfs show a marked asymmetry in the Galactic rest frame, which suggests that this population may be, on average, counter-rotating with respect to the Galactic disk. This may have interesting implications on models of Galactic formation.

222.06 – **Carbon-Enhanced Metal-Poor (CEMP) Stars in the Halo System of the Galaxy and Their Link with High Redshift Damped Lyman Alpha Systems**

Timothy C. Beers[1], D. Carollo[2], Y. Lee[1], C. R. Kennedy[2], SEGUE Collaboration

[1]*Michigan State Univ.,* [2]*RSAA, Australian National Univ., Australia.*

3:15 PM - 3:27 PM

It has been recognized for some time that the halo system of the Galaxy exhibits a large fraction of metal-poor stars with significant over-abundances of carbon, [C/Fe] > +0.7. These are known collectively as Carbon-Enhanced Metal-Poor (CEMP) stars. The great majority of these stars, roughly 80%, exhibit heavy element abundance patterns typically associated with the s-process (CEMP-s), and hence are thought to be produced by mass transfer from the envelope of a binary companion that has passed through the AGB stage. However, roughly 20% of the so-called stars show no enhancements of neutron-capture elements. The CEMP-no stars are also primarily found at lower metallicity, and dominate samples of halo CEMP stars with [Fe/H] < -2.5. After summarizing the nature of the CEMP stars, I present an argument that the inner halo of our Galaxy is dominated by the CEMP-s variety of such stars, while the outer halo is dominated by the CEMP-no stars. This inference may provide insight into the origin of the two populations, and the nucleosynthetic production of carbon and other light elements in the earliest generations of stars, thus completing the link between local metal-poor stars and high-redshift Damped Lyman Alpha (DLA) systems.

T.C.B. and Y.S.L. acknowledge partial funding of this work from grants PHY 02-16783 and PHY 08-22648: Physics Frontier Center/Joint Institute for Nuclear Astrophysics (JINA), awarded by the U.S. National Science Foundation.

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223 – Galaxy Cluster Masses and Dynamics

Oral Session – Room 12B – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

223.01 – **Dynamic Analysis of CLASH Clusters**

Doron Lemze[1], M. Geller[2], M. Nonino[3], E. Medezinski[1], M. Postman[4], H. Ford[1], M. Kurtz[2], K. Rines[5], CLASH team

[1]*Johns Hopkins University,* [2]*Smithsonian Astrophysical Observatory,* [3]*INAF -*

Astronomical Observatory of Bologna, Italy, [4]The Space Telescope Science Institute, [5]Western Washington University.
2:00 PM - 2:10 PM

Some tension was found between the mass distributions derived in simulations and inferred from observations. The Cluster Lensing And Supernova survey with Hubble (CLASH) is a 524-orbit multi-cycle treasury program to use the gravitational lensing properties of 25 galaxy clusters to accurately constrain their mass distributions (Postman et al. 2011). Here we put constrains on the mass distribution by dynamically analyzing Hectospec spectroscopic redshifts, using hundreds of redshifts per cluster for about five of CLASH clusters. These are confronted with results derived from lensing on the one hand and with published theoretical expectations on the other.

223.02 – **CLASH: Are Galaxy Cluster Cores Denser In Nature Than In Simulations? New Results For Abell 2261 Based On 16-band Hubble Imaging And Lensing, X-ray, And Dynamical Analyses.**

Dan A. Coe[1], CLASH Team

[1]*STScI.*
2:10 PM - 2:20 PM

The best studied galaxy clusters appear to harbor denser cores than their counterparts realized in simulations. This suggests earlier formation times with possible cosmological implications, perhaps leading to clues regarding the nature of dark energy. However, the observational constraints must be strengthened by studying a larger and less biased cluster sample. This is one of the primary science goals of CLASH, The Cluster Lensing and Supernova survey with Hubble. Based on our 16-band Hubble imaging, we are performing detailed strong lensing analyses to map mass within the cores of 25 clusters. Our observations of Abell 2261 have enabled us to identify for the first time galaxies strongly lensed and multiply-imaged by this cluster. We combine this with revised modeling of the weak gravitational lensing observed at larger radii in Subaru imaging. Based on our lensing, X-ray, and dynamical analyses, we derive the mass profile of Abell 2261 and compare its core density concentration to clusters of similar mass formed in simulations. We include novel estimates of important systematic uncertainties such as cluster elongation (triaxiality) and additional massive structures along our line of sight.

223.03 – **Using Caustic Methods to Measure the Masses of Galaxy Clusters**

Daniel Gifford[1], C. J. Miller[1], C. D. Harrison[1], M. Kao[2], M. T. Busha[3], R. H. Wechsler[3], A. E. Evrard[1]

[1]*University of Michigan, [2]California Institute of Technology, [3]KIPAC/Stanford University.*
2:20 PM - 2:30 PM

The ability to estimate galaxy cluster masses with a known systematic scatter for large cluster samples has become very valuable with the advent of large photometric and spectroscopic surveys. The caustic method has the capability to estimate masses for a wide range of halo sizes with no assumptions about the equilibrium of the system and can be applied using spectroscopic follow-up to any large survey. We use the most recent synthetic catalog created by the Dark Energy Survey collaboration to better constrain the systematic scatter in mass estimation both on individual clusters and stacked systems, while examining the effects of adding in observable systematics, including uncertainties in the radii, as well as different optical targeting algorithms. We also show how line-of-sight projections affect the caustic-inferred masses. This builds upon previous work which identified uncertainties using N-body simulations. We find that to reduce the scatter in caustic mass estimates to around 20%, a magic number of at least 50 galaxies with spectroscopic redshifts are needed within the virial radius of the cluster. The work of Dan Gifford is supported by the National Science Foundation Graduate Research Fellowship.

223.04 – **Galaxy Cluster Dynamics and Substructure with ACRES: The Arizona Cluster Redshift Survey**

Maria Pereira[1], E. Egami[1], C. Haines[1], E. Hardegree-Ullman[2]

[1]*Steward Observatory, [2]Rensselaer Polytechnic Institute.*
2:30 PM - 2:40 PM

We present results from ACRES (the Arizona Cluster REdshift Survey), our recently completed wide-field spectroscopic survey of 30 clusters at z~0.2 with Hectospec/MMT. With > 300 redshifts per cluster within ~2-3 virial radii and a total of 10,000 cluster galaxy redshifts, we are able to probe the dynamics of the infall regions of a large sample of clusters for the first time. These clusters are selected from the LoCuSS sample, and have a wealth of auxiliary multi-wavelength data. We will introduce the survey and use the rich phase space information to quantify the amount of 3D substructure in our cluster sample, which we then directly compare to estimates of substructure from gravitational lensing and X-ray studies. We discuss the importance of projection effects and the consequent need for multi-wavelength data in order to properly constrain the recent accretion history of each cluster as well as the effect these merger events might have on the cluster galaxy population and ICM.

223.05D – **CARMA And maxBCG: Covariance And Scaling Of SZ Signal And Richness In An Optically-selected Galaxy Cluster Sample**

Christopher Greer[1]

[1]*Univ. of Chicago.*
2:40 PM - 3:00 PM

Galaxy clusters are among the most sensitive dark energy probes, but their utility will be increasingly limited by systematic uncertainty in cluster mass estimation. The use of multi-wavelength cluster data is one way to mitigate this limitation. Such a combination will be possible due to significant overlap of current and near-future cluster surveys, particularly the South Pole Telescope (SPT) and the Dark Energy Survey (DES). I present the results of a pilot study that simultaneously uses optical data from the Sloan Digital Sky Survey and Sunyaev-Zel'dovich observations from CARMA to improve our understanding of joint cluster scaling relations. The results from this work will inform cosmological analyses of SPT+DES cluster samples.

223.06D – **Weak Lensing Results of the Merging Cluster A1758**

Brett A. Ragozzine[1], D. I. Clowe[1]

[1]*Ohio University.*
3:00 PM - 3:20 PM

Here we present the weak lensing results of A1758N, which agree with previous weak lensing results of merging clusters such as 1E0657-558 (Bullet cluster) and MACS J0025.4-1222, whose X-ray gas components were found to be largely separated from their clusters' gravitational potentials. A1758N has a geometry that is different from previously published mergers in that one of its X-ray peaks overlays the corresponding gravitational potential and the other X-ray peak is well separated from its cluster's gravitational potential. The weak lensing mass peaks in A1758N are separated at the 2.5 σ level. We estimate the combined mass of the clusters in A1758N to be $2.2 \pm 0.5 \times 10^{15}$ M⊙ and $r_{200}=2300\text{-}130^{+100}$ kpc. We also detect seven strong lensing candidates, two of which may provide information that would improve the mass measurements of A1758N.

Support for program HST-GO-11194.01-A 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. DC also acknowledges support from the Alfred P. Sloan Foundation.

223.07 – **Discovery of a Galaxy Cluster Merger in Unexplored Merger Phase-space**

William Dawson[1], D. Wittman[1], J. Jee[1], P. Gee[1], J. P. Hughes[2], D. Marrone[3], A. Tyson[1], S. Schmidt[1], S. Muchovej[4], P. Thorman[1], J. Carlstrom[5], M. Bradac[1], S. Miyazaki[6], T. Mroczkowski[7], B. Lemaux[1], Y. Utsumi[6]

[1]*University of California Davis, [2]Rutgers University, [3]University of Arizona, [4]Caltech, [5]University of Chicago, [6]The Graduate University for Advanced Studies, Japan, [7]University of Pennsylvania.*
3:20 PM - 3:30 PM

We present DLSCL J1916.2+2951 (*z=0.53*), a newly discovered major cluster merger in which the collisional cluster gas has become separated from the collisionless galaxies and dark matter. Our identification of the system as a dissociative merger using only optical, weak-lensing, and Sunyaev-Zel'dovich effect observations shows that these systems can be found independently of X-ray observations. We confirm the post-merger scenario using follow-up observations with Keck, Subaru, Hubble Space Telescope, and Chandra, and constrain the dark matter self-interaction cross-section $\sigma_{DM}m_{DM}^{-1}<7$ cm^2g^{-1}. The system is observed at least 0.7±0.2 Gyr since first pass-through, thus providing a picture of cluster mergers 2-5 times further progressed than similar systems observed to date. This improved temporal leverage has implications for our understanding of merging clusters and their impact on galaxy evolution.

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224 – The Sun, Stellar Atmospheres, and Winds

Oral Session – Room 18D – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

224.01 – **X-ray Emissions from Clump Bowshocks in Massive Star Winds**

Richard Ignace[1], W. Waldron[2], J. Cassinelli[3]

[1]*East Tennessee State Univ., [2]Eureka Scientific Inc, [3]University of Wisconsin.*
2:00 PM - 2:10 PM

Clumped structures in wind flows have substantially altered our interpretations of multiwavelength data for understanding mass loss from massive stars. Embedded wind shocks have long been the favored explanation for the hot plasma production and X-ray

generation in massive star winds. This contribution reports on line profile shapes from the clump bowshock model and summarizes the temperature and emission measure distributions throughout the wind for this model with a focus on results that can be tested against observations.

The authors acknowledge funding support for this work from a NASA grant (NNH09CF39C).

224.02 – **The First Direct Measurement of an Early B Supergiant X-ray Source Electron Density**

Wayne L. Waldron[1], J. P. Cassinelli[2], N. A. Miller[3], E. M. Schlegel[4]

[1]Eureka Scientific, Inc., [2]University of Wisconsin-Madison, [3]University of Wisconsin-Eau Claire, [4]University of Texas-San Antonio.

2:10 PM - 2:20 PM

The ratio of the He-like ion forbidden to intercombination emission lines (*f/i*) provides a diagnostic for determining either the electron density of an X-ray source (collisional-dominated), or the X-ray source spatial location relative to a central EUV/UV radiation source (radiation-dominated). With the advent of high energy resolution spectroscopy, this diagnostic has become a well proven technique for determining the radial distribution of X-ray sources in OB stellar winds. However, in high energy ions (e.g., Si XIII) where the strength of this ratio is controlled by the radiation shortward of the Lyman edge, we show that there is an expected transition from radiation-dominance to collisional-dominance in the early B star spectral range. Because the photospheric flux is weak in the spectral energy region controlling the Si XIII *f/i* line ratio, we can probe stellar wind distributed X-ray source models from a different perspective and address fundamental issues pertaining to the origin of OB stellar X-ray emission. To verify this behavior we obtained four *Chandra* HETGS observations of the early B supergiant κ Ori (B0.5Ia) over a time span of approximately 10 days (total exposure = 234 ks). These observations allow us to explore the expected transition to collisional dominance. But, more importantly, our analysis of the Si XIII *f/i* line ratio has revealed the first direct measurement of an X-ray source density (~ 10^{13} cm^{-3}). We discuss the implications of these results.

224.03 – **NoMaDS: The Northern Massive Dim Stars Survey**

Anne Pellerin[1], J. Maíz Apellániz[2], S. Simón-Díaz[3], R. H. Barbá[4]

[1]Texas A&M University, [2]Instituto de Astrofísica de Andalucía-CSIC, Spain, [3]Instituto de Astrofísica de Canarias, Spain, [4]Universidad de La Serena, Chile.

2:20 PM - 2:30 PM

We present the Northern Massive Dim Stars Survey (NoMaDS), a high-resolution spectroscopic campaign at the 9.2m Hobby-Eberly Telescope. The project aims at building the most complete and homogeneous spectroscopic database of hot, massive Galactic OB stars. NoMaDS is part of an international collaboration that combines observations from Chilean, Spanish, and Texan facilities. The contribution of NoMaDS is to complement the other sister surveys by providing high signal-to-noise echelle spectra (R=30000) of Galactic OB stars that are too faint for smaller ground-based telescopes. NoMaDS will provide a sample of about 200 stars, many of which have never been observed before at such a high resolution.

Here we present the details of the survey, as well as echelle spectra obtained with the High Resolution Spectrograph since May 2011. This includes spectra of standard OB stars, Wolf-Rayet stars, binary systems, and oblique magnetic rotators. This survey will provide unprecedented spectroscopic database for a more accurate spectral classification, a quantitative analysis using atmosphere modeling, the detection and follow up of the orbits of massive spectroscopic binaries as well as the study of diffuse interstellar bands.

224.04 – **High-Precision Stellar Diameters Compared with Stellar Atmosphere Models**

Anders M. Jorgensen[1], J. T. Armstrong[2], H. R. Schmitt[3], E. K. Baines[4], D. Mozurkewich[5], C. Tycner[6], D. Hutter[7], T. Hall[1]

[1]New Mexico Tech, [2]Naval Rsearch Laboratory, [3]Naval research laboratory, [4]Naval Research Laboratory, [5]Seabrook Engineering, [6]Central Michigan University, [7]Naval Observatory Flagstaff Station.

2:30 PM - 2:40 PM

In this paper we use the coherent integration technique to obtain extremely high precision stellar diameters as a function of wavelength in the visible band using observations from the Navy Optical Interferometer (NOI). We then compare these diameters with stellar atmosphere models as a function of wavelength. Coherent integration is a post-processing technique which corrects for atmospheric optical-path-difference shifts in interferometric data and allows, effectively, to increase the integration time of optical interferomtric data indefinitely by summing many short exposures suitably phase-shifted. This is significant because coherent integration, which allows the complex visibilities to be summed in phase, greatly improves the signal-to-noise ratio over traditional techniques which average squared visibilities. The improvement is particularly dramatic for faint targets, and/or when the visibility amplitude is very small. This is importan when measuring stellar diameters on resolving baselines that include visibility nulls. Those baselines best constrain the diameters. However in order to take full advantage of the null as a diameter measure it is necessary to obtain high-SNR measurements around the null, which is possible with coherent integration. We present wavelength-dependent uniform disk diameter measurements with precision up to 1:500 to 1:1000. We then compare these with the corresponding uniform-disk diameters obtained from stellar atmosphere models.

224.05 – **Self-Obscured Dusty Massive Stars in Nearby Galaxies**

Rubab M. Khan[1], K. Z. Stanek[1], C. S. Kochanek[1]

[1]Ohio State University.

2:40 PM - 2:50 PM

When very massive evolved stars are optically obscured by dust from their own mass loss, much or even all of the stellar flux is re-emitted by their dusty envelopes leading to SEDs with peak luminosities in the mid-IR. The large, rich, publicly available Spitzer data-sets are ideal for identifying and studying such objects undergoing a very short but critical evolutionary phase. We present preliminary results from a systematic survey for rare, luminous, dusty, massive stars in nearby (D < 10 Mpc) galaxies. We identify the brightest mid-IR sources in archival Spitzer images, attempt to classify them and to characterize massive stellar population in the local neighborhood. We also present spectroscopic observations of "Object X", the brightest mid-IR star in the nearby galaxy M33, which has properties similar to those of the Galactic OH/IR star IRC+10420. The existence and rarity of these objects are an important probe of episodic mass loss in evolved massive stars. We consider their implication for our current understanding of massive stellar evolution.

224.06 – **Role of Evolving Coronal Holes in the Occurrence of Solar Activity**

Rajendra Shelke[1]

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2:50 PM - 3:00 PM

In this paper, the role of evolving coronal holes in the occurrence of eruptive phenomena on the Sun has been studied. Using subtraction method and the H-alpha synoptic charts of Carrington rotations 1716 -1746, the parts of KPNO 10830 Å coronal holes that are formed and/or disappeared from one synoptic map to another have been identified and compared with the positions of evolutionary changes in polarity reversal boundaries, prominences and Unipolar Magnetic Regions (UMRs).

Our results show that:

1.Coronal holes are not entirely passive if they are evolving.

2.There exists a physical relationship of newborn coronal holes and/or “Newly Formed Coronal Hole Areas” (NFOCHAs) with the disappearance of three solar features, namely prominences, polarity reversal boundaries and/ or UMRs.

3.The newborn coronal holes and polar & low-latitude NFOCHAs emerge in the succeeding rotations at the locations that had been the positions of polarity reversal boundaries and prominences in the preceding rotations.

4.There are 124 cases of NFOCHAs that demonstrate their association with complete and partial disappearance of polarity reversal boundaries with or without prominences.

5.A newborn coronal hole of one polarity emerges in the aftermath of complete or partial disappearance of the UMR of opposite polarity along with polarity reversal boundary circumscribing the UMR.

6.Most of the associated newborn coronal holes are long-lived and last for several solar rotations.

Our results demonstrate that the polarity reversal boundary erupts either by a mechanism that leads to the opening of pre-existing closed magnetic structures into a new coronal hole, which can support mass motion including an erupting prominence or alternately by some more fundamental process, which, under suitable conditions, can trigger the eruption of polarity reversal boundary with overlying quiescent prominence and also form a new coronal hole at the eruption site.

224.07 – **Advantage of Forbidden Emission Lines Over Extreme Ultraviolet Lines as Coronal Diagnostic Tools**

Shadia R. Habbal[1], M. Druckmuller[2], H. Morgan[1], A. Ding[3]

[1]Univ. of Hawaii at Manoa, [2]Brno University of Technology, Czech Republic, [3]Institute of Technical Physics, Germany.

3:00 PM - 3:10 PM

Space-based observations, starting in the late sixties and early seventies, established the frontier for exploring coronal emission (from the Sun and stars) in the ultraviolet, extreme ultraviolet and x-rays. Recently, these wavelengths have been the prime line-up for imaging experiments on solar and heliospheric space-based observatories, such as SOHO, Trace, STEREO, Hinode, and SDO. Such is also the case for the recently approved Solar Orbiter mission. Using recent examples from total solar eclipses, we show how probing the physics of the corona is seriously short-changed without the inclusion of coronal forbidden lines, such as the Fe X 637.4 nm, Fe XI 789.2 nm and Fe XIV 530.3 nm lines. The diagnostic potential of these spectral lines stems primarily from

the strength of their resonantly excited component compared to their EUV and X-rays counterparts where it is absent.

224.08 – **Chromospheric Explosions: Linking Observations Toward a Physical Model**

Michael S. Kirk[1], K. S. Balasubramaniam[2], J. Jackiewicz[1], R. T. J. McAteer[1], B. J. McNamara[1]

[1]*New Mexico State University,* [2]*Air Force Research Laboratory.*
3:10 PM - 3:20 PM

Bright points are observed routinely in every layer of the Sun. One type of bright point, called sequential chromospheric brightening (SCB), is coincident with flares and is thought to represent a chromospheric foot-point of a magnetic field line that extends into the corona. These field lines are energized during a CME-causing eruption leading to the brightening we observe. We extract physical measurements of chromospheric flares and SCBs using an automated feature detection suite. Correlating these results with complementary data from the corona, we identify the spatio-temporal relationship between coronal loops and SCBs. We explore a coronal origin for SCBs and put forth an explicatory model.

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225 – AGN, QSO, Blazars IV

Oral Session – Room 17A – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

225.01 – **Parsec-Scale Radio Emission from The Low-Luminosity AGN in the Dwarf Starburst Galaxy Henize 2-10**

Amy E. Reines[1], A. T. Deller[2]

[1]*National Radio Astronomy Observatory,* [2]*ASTRON Netherlands Institute for Radio Astronomy, Netherlands.*
2:00 PM - 2:10 PM

A candidate accreting massive black hole has recently been identified at the center of the vigorously star-forming, bulgeless dwarf galaxy, Henize 2-10. We present VLBI observations of Henize 2-10 at 1.4 GHz taken with the Long Baseline Array, and clearly detect parsec-scale radio emission at the precise location of the putative black hole. We also detect a second compact radio source away from the nucleus that is spatially coincident with a young massive super star cluster and almost certainly related to supernova activity. The observations presented here, in combination with multi-wavelength ancillary data, support the case for a low-luminosity active galactic nucleus in this dwarf starburst galaxy.

225.02 – **The Evolution of AGN and their Host Galaxies to z~1 in Wide-field Multi-wavelength Surveys**

Andy D. Goulding[1], DEEP2 survey team

[1]*Harvard Smithsonian CfA.*
2:10 PM - 2:20 PM

Galaxy properties (i.e., luminosity, color, morphology, star-formation history) are known to evolve strongly with time. The redshift z~0.5-1.5 is believed to be a crucial epoch: (1) galaxies are evolving strongly as a function of stellar mass; (2) AGN activity is prevalent; (3) massive clusters are forming and (4) the red sequence is becoming established. To unambiguously determine the dominant physical processes which are driving the growth and evolution of galaxies and their central black holes at z~1 requires sensitive multi-wavelength wide-field surveys. We have combined the AGN identified in sensitive Chandra ACIS-I X-ray imaging (~3200 sources; Goulding et al. 2011b), Spitzer IRAC infrared photometry (~4800 sources), and FIRST and NVSS radio data (~700 sources) with the Keck/DEIMOS catalog of ~49,600 optical spectroscopic galaxies in the combined ~3.2 deg^2 DEEP2 fields. Using this extensive suite of multi-wavelength data, we have identified ~2100 DEEP2 galaxies at z~0.8-1.4, which have signatures of X-ray, IR and/or radio-bright AGN. By comparing the properties of AGN in DEEP2 at z~0.8-1.4 to those of AGN in BOOTES at z~0.3-0.8 (Hickox et al. 2009), we place new direct wavelength-independent constraints on the evolution of AGN hosts. We find that whilst there is clear evidence for mass/luminosity downsizing from z~1 to the present day, there appears to be no evolution in color or morphology at this epoch, regardless of AGN accretion mode. However, from X-ray stacking analyses of IR AGN and star-forming galaxies, we find strong evidence for a large population of gas-rich (star-forming) obscured AGN which are formally undetected in the deep X-ray imaging. Taken together, this provides further indication that dust/gas rich systems may play a crucial role in galaxy evolution and the build-up of the red-sequence.

225.03D – **Roche Accretion Of Stars Close To Massive Black Holes**

Lixin J. Dai[1], R. Blandford[1]

[1]*KIPAC / Stanford University.*
2:20 PM - 2:40 PM

We consider the Roche accretion in an Extreme Mass-Ratio Inspiral (EMRI) binary system formed by a star orbiting a massive black hole. The ultimate goal is to constrain the mass and spin of the black hole and confirm general relativity in the strong-field regime from the resulted quasi-periodic signals. Before accretion starts, the star orbits the hole in a circular, equatorial stellar orbit, which shrinks due to gravitational radiation. New fitting formulae are presented for the inspiral time and the radiation-reaction torque in the relativistic regime. If the inspiralling star fills its Roche lobe outside the Innermost Stable Circular Orbit (ISCO) of the hole, gas will flow through the inner Lagrange point (L1) to the hole. We give new relativistic interpolation formulae for the volume enclosed by the Roche lobe. If this mass-transfer happens on a time scale faster than the thermal time scale but slower than the dynamical time scale, the star will evolve adiabatically, and, in most cases, will recede from the hole filling its Roche lobe. We calculate how the stellar orbital period and mass-transfer rate will change through the "Roche evolution" for various types of stars in the relativistic regime. We envisage that the mass stream eventually hits the accretion disc, where it forms a hot spot orbiting the hole and may ultimately modulate the luminosity with the stellar orbital frequency. The observability of such a modulation is discussed along with possible interpretation of an intermittent 1 hour period in the X-ray emission of RE J1034+396.

225.04 – **Chandra X-ray and HST Imaging of Kiloparsec-scale Binary Active Galactic Nuclei**

Xin Liu[1], Y. Shen[1], F. Civano[1], P. Green[1], J. Greene[2], M. Strauss[2]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Princeton University.*
2:40 PM - 2:50 PM

Kiloparsec-scale AGN pairs denote co-rotating massive black holes (MBHs) in merging galaxies, which may hold important clues to our general understanding of massive galaxy formation, of the hierarchical merger paradigm, and of MBH mergers predicted to be the primary source of low-frequency gravitational waves. Despite their significant merit, kpc AGN pairs remained difficult to find. We developed a feasible approach to systematically identify kpc AGN pairs based on the selection of AGNs with double-peaked narrow emission lines combined with follow-up higher resolution near-infrared (NIR) imaging and spatially resolved optical spectroscopy. While our results suggest that the majority of double-peaked narrow-line AGNs are single AGNs with complex gas kinematics, at least ~1/10 seem to be kpc AGN pairs. Here we present Chandra X-ray and HST imaging of four such kpc AGN pairs identified in our systematic search. We use the detection of two luminous X-ray nuclei in each galaxy to confirm the double AGN nature unambiguously. We exploit HST NIR and UV imaging to characterize host galaxy morphology and star formation activity of these merging systems in unprecedented detail.

225.05 – **Spatially Resolved Spectroscopy of SDSS J0952+2552: A Confirmed Dual Active Galactic Nucleus**

Rosalie C. McGurk[1], C. E. Max[1], D. J. Rosario[2], G. A. Shields[3], K. L. Smith[3], S. A. Wright[4]

[1]*UC Santa Cruz,* [2]*Max-Planck-Institute for Extraterrestrial Physics, Germany,* [3]*UT Austin,* [4]*UC Berkeley.*
2:50 PM - 3:00 PM

Most massive galaxies contain supermassive black holes in their cores. When galaxies merge, gas is driven to nuclear regions and can accrete onto the central black hole. Thus, one expects to see dual active galactic nuclei (AGNs) in a fraction of galaxy mergers. Candidates for galaxies containing dual AGNs have been identified by the presence of double-peaked narrow [O III] emission lines and by high spatial resolution images of close galaxy pairs. Spatially resolved spectroscopy is needed to confirm these galaxy pairs as systems with spatially separated double AGNs. With the Keck 2 Laser Guide Star Adaptive Optics system and the OSIRIS near-infrared integral field spectrograph, we obtained spatially resolved spectra for SDSS J09527.62+255257.2, a radio-quiet quasar shown by previous imaging to consist of a galaxy and its close (1.0" = 4.8 kpc) companion. We find that the main galaxy is a Type 1 AGN with both broad and narrow AGN emission lines in its spectrum, while the companion galaxy is a Type 2 AGN with narrow emission lines only. Their redshifts correspond to those of the double peaks of the [O III] emission line seen in the SDSS spectrum. Line diagnostics indicate that both components of the double emission lines are due to AGN photoionization. These results confirm that J0952+2552 contains two spatially separated AGNs. Future observations of more spatially separated double-peaked emission line AGN with separations <10 kpc will offer a unique opportunity to study galaxy mergers and their effect on black hole growth.

225.06D – **Detecting Dual AGN at High Redshift**

Robert S. Barrows[1]

[1]*University of Arkansas.*
3:00 PM - 3:20 PM

The existence of supermassive black holes (SMBHs) in most, if not all, galaxies, along

with observations of galaxy mergers, suggests that pairs of SMBHs should exist for some time in the merger remnant. Observational evidence for these systems at kpc-scale separations (i.e. dual AGN) has dramatically increased recently through a combination of spectral and morphological selections. I discuss observations of CXOXBJ142607.6+353351 (CXOJ1426+35), a candidate dual AGN at z=1.175, and put its properties, including significant obscuration, within the context of other candidate/confirmed dual AGN at lower redshifts. Though dual AGN are expected to be more common at higher redshifts, they are more difficult to detect. Furthermore, adding to the difficulties of detection are a number of other physical mechanisms which can mimic the spectroscopic signature of two Type 2 AGN. In particular, I will discuss the possibility of strong outflows from an AGN. These outflow phenomena can be an important feedback mechanism in galaxies and are apparently common in AGN, making them a viable alternative to the dual AGN scenario. Based on our candidate's luminosity and emission line intensities, we find that an outflow is a possibility. If this is the case, such an outflow would be especially strong and has implications for AGN feedback in galaxies. However, the dual AGN scenario cannot be ruled out, and at z=1.175, the two putative AGN could potentially be resolved with Chandra. Other candidate dual AGN at similar redshifts and with significant obscuration could also be confirmed this way. This research was sponsored by the Strategic University Research Partnership Program, the National Aeronautics and Space Administration and the Arkansas NASA EPSCoR program.

225.07 – **Identifying Luminous AGN in Deep Surveys: Revised IRAC Selection Criteria**

Jennifer Donley[1], A. M. Koekemoer[1], M. Brusa[2], P. Capak[3], C. N. Cardamone[4], F. Civano[5], O. Ilbert[6], C. D. Impey[7], J. Kartaltepe[8], T. Miyaji[9], M. Salvato[2], D. B. Sanders[10], J. R. Trump[11], G. Zamorani[12]

[1]Space Telescope Science Institute, [2]MPE, Germany, [3]Caltech, [4]MIT, [5]Harvard Smithsonian Center for Astrophysics, [6]Laboratoire d'Astrophysique de Marseille, France, [7]Univeristy of Arizona, [8]NOAO, [9]Universidad Nacional Autónoma de México, Mexico, [10]University of Hawaii, [11]UCO/Lick, [12]INAF-Osservatorio Astronomico di Bologna, Italy.

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Spitzer IRAC selection is a powerful tool for identifying luminous AGN. The AGN selection wedges currently in use, however, are heavily contaminated by star-forming galaxies, especially at high redshift. Using the large samples of luminous AGN and high-redshift star-forming galaxies in COSMOS, we redefine the AGN selection criteria for use in deep IRAC surveys. The new IRAC criteria are designed to be both highly complete and reliable, and incorporate the best aspects of the current AGN selection wedges and of infrared power-law selection while excluding high redshift star-forming galaxies selected via the BzK, DRG, LBG, and SMG criteria. At QSO-luminosities of log L(2-10 keV)>44, the new IRAC criteria recover 75% of the hard X-ray and IRAC-detected XMM-COSMOS sample, yet only 37% of the IRAC AGN candidates have X-ray counterparts, a fraction that rises to 51% in regions with Chandra exposures of 50-160 ks. X-ray stacking of the individually X-ray non-detected AGN candidates leads to a hard X-ray signal indicative of heavily obscured to mildly Compton-thick obscuration (log N_H >= 23.7). While IRAC selection recovers a substantial fraction of luminous unobscured and obscured AGN, it is incomplete to low-luminosity and host-dominated AGN.

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226 – HEAD IV: New Results in High Energy Astrophysics

Oral Session – Room 18B – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

226.01 – **The X-ray Brightest Group in the Sky - NGC 5044**

Laurence P. David[1], E. O'Sullivan[2], S. Giacintucci[3], W. Forman[1], C. Jones[1], J. Vrtilek[1], S. Raychaudhury[4], M. Sun[5], J. Lim[6]

[1]Harvard Smithsonian Center for Astrophysics, [2]University of Birminghman, United Kingdom, [3]University of Maryland, [4]University of Birmingham, United Kingdom, [5]University of Virginia, [6]University of Hong Kong, Hong Kong.

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A Chandra observation of the X-ray bright group NGC 5044 shows that the X-ray emitting gas in this system has been strongly perturbed by several recent AGN outbursts. The NGC 5044 group hosts many small X-ray cavities, cool filaments and cold fronts. The cool X-ray filaments share the same morphology as the Ha filaments. CO emission has also been detected in the center of the group were the X-ray emitting gas is the coldest. We can thus study the properties of the fully ionized, atomic and molecular gas in NGC 5044 to better understand the nature of the gas cooling. Low frequency GMRT observations revel a complicated radio morphology and show the presence of at least three separate outbursts. Some of the radio emission fills the larger X-ray cavities, but the smaller X-ray cavities remain undetected. Since the smaller bubbles are probably no longer momentum driven by the central AGN, their motion will be affected by the group "weather" as they buoyantly rise outward. A detailed spectroscopic analysis shows that the central region of NGC 5044 contains significant amounts of multiphase gas. The regions with the most inhomogeneous gas tend to correlate with the extended radio emission. This may result from gas entrainment within the radio emitting plasma. All of our results indicate that the gas re-heating mechanism in NGC 5044 is significantly different from that typically found in rich clusters, where powerful bi-polar radio outbursts are usually observed. In NGC 5044, the gas has probably been reheated by nearly continuous, weak AGN outbursts which produce weather-driven bubbles and a nearly isotropic deposition of energy.

226.02D – **Multi-Zone Modeling of Nonthermal Radiation from Pulsar Wind Nebulae**

Adam Van Etten[1], R. W. Romani[1]

[1]Stanford University.

2:10 PM - 2:30 PM

Many pulsar wind nebulae (PWN) are spatially resolved in the radio, X-ray, and even very high energy (VHE) wavebands, and thereby provide an excellent laboratory to study not only pulsar winds and dynamics, but also shock processes, the ambient medium, magnetic feld evolution, and particle transport. Single-zone spectral energy distribution (SED) models have long been used to study the global properties of PWN, but to fully take advantage of high resolution data one must move beyond these simple models. I describe 3-D time-dependent PWN spectral energy distribution modeling, with particular emphasis on the spatial variations within the large and bright PWN associated with PSR J1826−1334, HESS J1825−137. Within this PWN, the gamma-ray spectral index is observed to soften with increasing distance from the pulsar, likely the result of cooling losses as electrons traverse the nebula. The large size and high nebular energy budget imply a relatively rapid initial pulsar spin period of 13±7 ms and an age of 40±9 kyr. The relative fluxes of each VHE zone can be explained by advective particle transport with a radially decreasing velocity profile with $v(r) \sim r^{(-0.5)}$. The evolution of the cooling break requires an evolving magnetic field which also decreases radially from the pulsar, $B(r,t) \sim r^{(-0.7)} Edot(t)^{(0.5)}$. Detection of 10 TeV flux ~80 pc from the pulsar requires rapid diffusion of high energy particles with $\tau esc \approx 90 (R/10\ pc)^2 (E/100\ TeV)^{(-1)}$ year, contrary to the common assumption of toroidal magnetic fields with strong magnetic confinement. The model predicts a rather uniform Fermi LAT surface brightness out to ~1 degree from the pulsar, in good agreement with the recently discovered LAT source centered 0.5 degree southwest of PSR J1826−1334 with extension 0.6±0.1 degree. The growing number of sources with spatially resolved X-ray and VHE measurements (e.g. Vela-X, HESS J1303-631) are prime targets for such multi-zone modeling.

226.03 – **Resolving the Bondi Accretion Flow toward the Supermassive Black Hole of NGC 3115 with Chandra**

Ka-Wah Wong[1], J. Irwin[1], M. Yukita[1], E. Million[1], W. Mathews[2], J. Bregman[3]

[1]Univ. of Alabama at Tuscaloosa, [2]UCSC, [3]Univ. of Michigan.

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Gas undergoing Bondi accretion onto a supermassive black hole (SMBH) becomes hotter toward smaller radii. We searched for this signature with a 150 ks Chandra observation of the hot gas in NGC 3115, which optical observations show has a very massive SMBH. Our analysis suggests that we are resolving, for the first time, the accretion flow within the Bondi radius of an SMBH. We show that the temperature is rising toward the galaxy center as expected in all accretion models in which the black hole is gravitationally capturing the ambient gas. There is no hard central point source that could cause such an apparent rise in temperature. The data support that the Bondi radius is at about 4"-5" (188-235 pc), suggesting an SMBH of 2×10^9 M_{sun} that is consistent with the upper end of the optical results. The density profile within the Bondi radius has a power-law index of $1.03^{+0.23}$ - 0.21, which is consistent with gas in transition from the ambient medium and the accretion flow. The accretion rate at the Bondi radius is determined to be 0.022 solar mass per year. Thus, the accretion luminosity with 10% radiative efficiency at the Bondi radius (10^{44} erg s^{-1}) is about six orders of magnitude higher than the upper limit of the X-ray luminosity of the nucleus. Our 1 Ms Chandra X-ray Visionary project to further study the galaxy will be briefly introduced.

226.04 – **Imaging Quasar Coronae Using Gravitational Microlensing**

Bin Chen[1], X. Dai[1], C. S. Kochanek[2], G. Chartas[3], J. A. Blackburne[2], S. Kozlowski[4]

[1]University of Oklahoma, [2]The Ohio State University, [3]College of Charleston, [4]Warsaw University Observatory, Poland.

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Gravitational microlensing provides a unique probe to study the innermost part of quasar accretion disks close to the event horizon of supermassive black holes. We report our long-term monitoring data using Chandra for five gravitationally lensed quasars: Q2237+0305, QJ0158-4325, SDSS0924+0219, SDSS1004+4112 and HE0435-1223. We discover for the first time chromatic microlensing differences between the soft and hard X-ray bands in the X-ray continuum emission. Our results indicate that the coronae above the accretion disk thought to generate X-rays have a non-uniform electron distribution, and the hard X-ray emission may track the event horizon of black holes. We detect metal emission lines for all X-ray images in all lenses. This enables us to compare the microlensing variability between the X-ray continuum and metal emission lines and constrain the metal line emission regions relative to the X-ray continuum. Our results also confirm earlier microlensing results that quasar X-ray emission regions are significantly smaller than the optical emission regions.

226.05 – **Optical Discovery of Stellar Tidal Disruption Flares**

Glennys R. Farrar[1], S. van Velzen[2]

[1]*New York University,* [2]*Radboud Univ., Netherlands.*

2:50 PM - 3:00 PM

We model the SED and light-curves of two probable tidal disruption flares (TDFs) found by van Velzen et al (2011) in a search for the tidal disruption of stars by super-massive black holes in non- active galaxies, using archival multi-epoch SDSS imaging data (Stripe 82). These flares were shown to be very difficult to reconcile with a SN or AGN-flare explanation, based on the SDSS observations, UV emission measured by GALEX and spectra of the hosts and of one of the flares. The flares have optical black-body temperatures 2×10^4 K and observed peak luminosities $M_g = -18.3$ and -20.4 ($\nu L_\nu = 5 \times 10^{42}$, 4×10^{43} erg/s, in the rest-frame); their cooling rates are very low, qualitatively consistent with expectations for tidal disruption flares. Best-fitting models for the observed SED and light curves are reported, and the rate of tidal disruption events is given. The possibility that tidal disruption flares produce Ultrahigh Energy Cosmic Rays is discussed. Fundamental questions in astrophysics and cosmology that can be addressed with a large sample of TDFs are enumerated.

226.06 – **Swift J164449.3+573451: Jet Emission from a Tidal Disruption Event - the 9 Month Update**

David N. Burrows[1], J. A. Kennea[1], P. Romano[2], V. Mangano[2], N. Gehrels[3]

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On March 28, 2011, the Swift Burst Alert Telescope triggered on an object that has no analog in over six years of Swift operations. Followup observations by the Swift X-ray Telescope have shown a new, bright X-ray source with highly variable flux (covering 3 orders of magnitude in flux over the first few days) that has been much more persistent than gamma-ray burst afterglows. Optical photometry shows a decaying NIR source coincident with the X-ray object. Ground-based spectroscopy found a redshift of 0.35, implying extremely high luminosity, with integrated isotropic X-ray energy output exceeding 10^{53} ergs in the first two weeks after discovery. Deep serendipitous archival X-ray observations show no counterpart over the past 20 years to fluxes orders of magnitude below the light curve peak values. There is strong evidence for a collimated (or beamed) jet. The observational properties of this object are unlike anything ever before observed. We interpret these unique properties as the result of emission from a relativistic jet produced in the aftermath of the tidal disruption of a star by a massive black hole in the center of the host galaxy. If so, we expect the source to decay slowly as the stellar remnants are accreted onto the central black hole. We will discuss the results of daily monitoring of this object by the Swift X-Ray Telescope for over 9 months.

226.07 – **Testing The Cas A Neutron Star Temperature Decline With Other Chandra Instruments**

Khaled Elshamouty[1], C. O. Heinke[1], W. C. G. Ho[2], D. J. Patnaude[3], P. S. Shternin[4], D. G. Yakovlev[4]

[1]*University of Alberta, Canada,* [2]*University of Southampton, United Kingdom,* [3]*Smithsonian Astrophysical Observatory,* [4]*Ioffe Physical Technical Institute, Russian Federation.*

3:10 PM - 3:20 PM

The neutron star in the Cassiopeia A supernova remnant is ~330 years old, making it the youngest neutron star in the Milky Way. Heinke & Ho (2010) reported a rapid cooling drop of 4% in its surface temperature (21% drop in observed flux) from Chandra ACIS-S archival data between 2000 and 2009. This opened the suggestion of enhanced neutrino emission due to a superfluid transition in the core to account for the observed rapid cooling (Page et al. 2011, Shternin et al. 2011). Here we present analysis of archival Chandra ACIS-I, HRC-I and HRC-S data over the same time period to test the rate. We used the best ACIS-S carbon atmosphere spectral fits to infer the countrates corresponding to various temperatures, along with current (CALDB 4.4.6) estimates of the effective area and its changes over time for these cameras, to calculate the temperature drops in each instrument. We find that the HRC-I data are consistent with the ACIS-S result, though tending to smaller declines. The ACIS-I data suggest a slightly larger drop. The HRC-S data (with the longest exposures) indicate a marginal temperature decline of 0.9+0.7-0.7 % (90% conf.) over 9 years.

226.08 – **Hard X-ray Emission by Resonant Compton Upscattering in Magnetars**

Zorawar Wadiasingh[1], M. G. Baring[1], P. L. Gonthier[2], A. K. Harding[3]

[1]*Rice Unversity,* [2]*Hope College,* [3]*NASA Goddard Space Flight Center.*

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For inner magnetospheric models of hard X-ray and gamma-ray emission in high-field pulsars and magnetars, resonant Compton upscattering is anticipated to be the most efficient process for generating continuum radiation. For magnetars, this is due in part to the proximity of a hot soft photon bath from the stellar surface. Moreover, the scattering cross section becomes resonant at the cyclotron frequency, exceeding the classical Thomson value by over two orders of magnitude and thereby enhancing the efficiency of continuum production and the cooling of relativistic electrons. We present angle-dependent hard X-ray upscattering model spectra for uncooled monoenergetic relativistic electrons injected in inner regions of pulsar magnetospheres. These spectra are integrated over closed field lines and obtained for different observing perspectives. Electron cooling rates for resonant Compton interactions are also presented, in preparation for future radiation-reaction limited acceleration and emission models of non-thermal magnetar X-rays. Our research employs a new Sokolov and Ternov (ST) formulation of the QED Compton scattering cross section in strong magnetic fields. Such an ST formalism is formally correct for treating spin-dependent effects that are important in the cyclotron resonance, and has not been addressed before in the context of Compton upscattering models of magnetar hard X-ray tail emission.

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227 – Astronomy 101 Teaching & Learning

Oral Session – Room 16A – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

227.01 – **Fostering the Development of Quantitative Life Skills through Introductory Astronomy: Can it be Done?**

Katherine B. Follette[1], D. W. McCarthy[1]

[1]*University of Arizona.*

2:00 PM - 2:10 PM

We present preliminary results from a student survey designed to test whether the all-important life skill of numeracy/quantitative literacy can be fostered and improved upon in college students through the vehicle of non-major introductory courses in Astronomy. Many instructors of introductory science courses for non-majors would state that a major goal of our classes is to teach our students to distinguish between science and pseudoscience, truth and fiction, in their everyday lives. It is difficult to believe that such a skill can truly be mastered without a fair amount of mathematical sophistication in the form of arithmetic, statistical and graph reading skills that many American college students unfortunately lack when they enter our classrooms. In teaching what is frequently their "terminal science course in life" can we instill in our students the numerical skills that they need to be savvy consumers, educated citizens and discerning interpreters of the ever-present polls, studies and surveys in which our society is awash? In what may well be their final opportunity to see applied mathematics in the classroom, can we impress upon them the importance of mathematical sophistication in interpreting the statistics that they are bombarded with by the media? Our study is in its second semester, and is designed to investigate to what extent it is possible to improve important quantitative skills in college students through a single semester introductory Astronomy course.

227.02D – **Understanding the Correlations Among Undergraduates' Spatial Reasoning Skills and Their Ability to Learn Astronomy Concepts**

Inge Heyer[1]

[1]*University of Wyoming.*

2:10 PM - 2:30 PM

We tacitly assume that astronomy is a conceptual domain deeply entrenched in three dimensions and that learners need to utilize spatial thinking to develop understanding of the field. In particular, cognitive science generally views students' spatial thinking abilities as something that can be enhanced through purposeful instruction, whereas aptitude and ability to learn complex ideas might be immutable. Yet, precise investigations into the underlying relationship between students' spatial reasoning ability and their ability to learn astronomy content in college science classes are beginning to reveal insight into how students cognitively engage in learning astronomy. In support, researchers at the CAPER Center for Astronomy and Physics Education Research

conducted a first-steps correlational study of 148 non-science majoring undergraduate students. Using a single group, multiple-measures, longitudinal study design, students' cognition was measured for pretest and posttest gains in astronomy understanding using established assessment tools, including the Test Of Astronomy STandards (TOAST) over the duration of instruction. In the middle of the semester they were tested for spatial reasoning ability using a subset of reliable spatial thinking assessment tools from the Spatial Intelligence and Learning Center (SILC). Results suggest some instructional techniques can be predicted as successful *a priori* while others are as yet unresolved. This work was supported, in part, by the Wyoming Excellence in Higher Education Endowment.

227.03 – **3D Virtual Reality for Teaching Astronomy**

Angela Speck[1], L. Ruzhitskaya[1], J. Laffey[1], N. Ding[1]

[1]*Univ. of Missouri.*

2:30 PM - 2:40 PM

We are developing 3D virtual learning environments (VLEs) as learning materials for an undergraduate astronomy course, in which will utilize advances both in technologies available and in our understanding of the social nature of learning. These learning materials will be used to test whether such VLEs can indeed augment science learning so that it is more engaging, active, visual and effective. Our project focuses on the challenges and requirements of introductory college astronomy classes. Here we present our virtual world of the Jupiter system and how we plan to implement it to allow students to learn course material - physical laws and concepts in astronomy - while engaging them into exploration of the Jupiter's system, encouraging their imagination, curiosity, and motivation. The VLE can allow students to work individually or collaboratively. The 3D world also provides an opportunity for research in astronomy education to investigate impact of social interaction, gaming features, and use of manipulatives offered by a learning tool on students' motivation and learning outcomes. Use of this VLE is also a valuable source for exploration of how the learners' spatial awareness can be enhanced by working in 3D environment. We will present the Jupiter-system environment along with a preliminary study of the efficacy and usability of our Jupiter 3D VLE.

227.04 – **Teaching Celestial Motions in Astronomy 101 using the Digital Fulldome Planetarium Environment**

Thomas J. Balonek[1], J. Eakin[1]

[1]*Colgate Univ..*

2:40 PM - 2:50 PM

We utilize the immersive fulldome digital planetarium capabilities of the Colgate University Ho Tung Visualization Laboratory (VisLab) in introductory astronomy courses to teach students about observable celestial motions. We are developing demonstrations and exercises in which students conduct realistic "observations" in the VisLab that complement observations that they make outside on clear nights. From these observations students determine the characteristics and time scales of motions of the various solar system objects. Using the VisLab it is possible for the students to observe the daily, monthly, annual and peculiar motions of the stars, Sun, Moon and planets that they would otherwise be unable to witness during the semester. Our "observation first" approach is to have students observe the various cycles of the sky early in the semester, and later explain the reasons for these motions when they learn about the historical developments in our understanding of the celestial motions.

227.05 – **Developing Resource Guides for Astro 101 Instructors, as a Higher Education Community Collaboration from the NASA Astrophysics SEPOF**

Gregory R. Schultz[1], A. Fraknoi[1], D. Smith[2], J. Manning[1]

[1]*Astronomical Society of the Pacific,* [2]*Space Telescope Science Institute.*

2:50 PM - 3:00 PM

The NASA/SMD-funded Astrophysics SEPOF (Science Education & Public Outreach Forum) has been organizing EPO "community collaborations" as part of its coordination efforts with missions and EPO programs within NASA Astrophysics. One of the community collaborations that emerged has been focusing on *higher education*, with a particular emphasis on introductory astronomy courses ("Astro 101"), and how NASA EPO programs and materials can help serve the needs of these courses' instructors. One of the consequent efforts that has begun is the compiling and development of topical Resource Guides for Astro 101 instructors, with the initial subject tackled being *cosmology*. This is an area in basic astronomy where rapid progress is being made, older textbooks are quickly out of date, and ideas are challenging for many students, and even instructors! We have had informal conversations so far with about a dozen instructors, divided among universities, liberal-arts colleges, and 2-year community colleges. We have also gathered feedback regarding suggested cosmology resources from the EPO community served by the NASA Astrophysics Forum. And we have undertaken an independent search for Astro 101-suitable curriculum materials, from NASA and other sources, and identified a useful set of such materials, in print and on the Web. Results from this investigation will be shared, along with our project's initial Cosmology Resource Guide, and plans for follow-up guides. Feedback is solicited from Astro 101 instructors, resource developers, and EPO professionals.

227.06 – **Astronomy in Sustainable Energy: A New Approach to Make It Matter**

Lanika Ruzhitskaya[1], A. Speck[1]

[1]*University of Missouri.*

3:00 PM - 3:10 PM

We present a study of a new approach to teaching non-science students concepts of sustainable energy using astronomy, real life and fictional scenarios. Teaching non-science majors about energy is important because of the challenge that scientific (il)literacy poses for tangible and political problems like energy.

We have established a course in which students are involved in critical thinking and the process of scientific reasoning while discovering the nature of energy and its role in our lives and its presentation in the fiction genre. In the course, students construct and apply their knowledge of transformation of energy to understanding of the concepts of the formation of the sun and the planets. Along with these concepts, students learn about ways of harnessing energy for sustaining life on Earth. During the course students transform their "Why do I care?" to "What can I do?" We are achieving this change by starting with a broad introduction of the concepts and physical laws involved in understanding of the Solar Nebular hypothesis during which we discuss the role of different forms of energy involved in the process. In the next step we narrow down the discussion to importance and use of energy on Earth and then we discuss the role of different forms of energy in maintaining our individual lives. Thus students go from intangible notions about energy to making informed decisions on what type of sustainable energy makes sense to use in their houses and how many burgers they want to eat per day.

Moving towards sustainable energy technologies requires a public who understands the science behind the issues. The work presented here is aimed at providing a mechanism for increase literacy regarding these issues and testing this mechanism's success.

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228 – Extrasolar Planets and Brown Dwarfs: Formation, Evolution

Oral Session – Ballroom F – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

228.01D – **Heterogeneous Giant Planet Thermal Evolution with MESA**

Neil Miller[1], J. Fortney[1]

[1]*UC Santa Cruz.*

2:00 PM - 2:20 PM

The MESA code, designed primarily at the KITP at UC Santa Barbara by Bill Paxton, provides a set of independent modules primarily designed

to perform stellar evolution calculations. We present an adapted version of MESA for the purpose of giant planet heterogeneous thermal evolution calculations. This is of particular interest for the modeling of giant planet thermal evolution in the face of core erosion or helium rain processes, since strong composition gradients can be encountered in these cases. MESA modules have been created or modified to describe the equation of state of mixtures of hydrogen, helium, and heavy elements (using ANEOS), to utilize an atmospheric boundary condition including strong incident stellar fluxes, to include relevant low-temperature atmospheric opacities, and modified mixing processes.

228.02 – **Candidates for Solar Siblings**

Mauri J. Valtonen[1], A. Myllari[2], A. Bajkova[3], V. Bobylev[3]

[1]*Univ. of Turku, Finland,* [2]*Abo Akademi University, Finland,* [3]*Pulkovo Astronomical Observatory, Russian Federation.*

2:20 PM - 2:30 PM

We search for solar siblings, the stars that could have formed with the Sun in a common "parent" open cluster. We select suitable candidates by the closeness of their space velocities to the solar velocity and analyze the parameters of their encounters with the Sun in the past 5 billion years. We consider stars with known 3D velocities and show that two stars, HIP 87382 and HIP 47399, are of considerable interest . Their orbits oscillate near the solar orbit with an amplitude of about 250 pc; there are short-term close encounters at distances <10 pc. Both stars have an evolutionary status and metallicity similar to the solar metallicity. It is possible that spores of life have been exchanged between our Solar system and the possible planetary systems of these stars. We recommend that these stars are included among special targets for search of Earth-class planets and for life in exoplanetary systems.

228.03 – **A Young Exoplanet Caught at Formation**

Adam L. Kraus[1], M. J. Ireland[2]

[1]*Univ. of Hawaii-IfA,* [2]*Macquarie University, Australia.*

2:30 PM - 2:40 PM

Young and directly-imaged exoplanets offer critical tests of planet-formation models that

can't be matched by RV surveys of mature stars. These targets have been extremely elusive to date, with no exoplanets younger than 10-20 Myr and only a handful of direct-imaged exoplanets at all ages. We recently reported the discovery of a likely young protoplanet around LkCa 15. This protoplanet is embedded in a protoplanetary disk with a large cleared gap (a ``transitional disk'') and appears to orbit within that gap. In this talk, we will present an update on those results, summarizing our new astrometric and photometric observations and discussing their implications for the orbital and structural properties of the protoplanet. We also will discuss this system in the context of our ongoing survey to identify planets in transition disk gaps, including the implications for the process, epoch, and duration of planet formation.

228.04D – **Giant Planet Companions to T Tauri Stars**

Christopher Crockett[1], N. Mahmud[2], L. Prato[3], C. Johns-Krull[2], D. T. Jaffe[4], P. Hartigan[2], C. A. Beichman[5]

[1]*USNO,* [2]*Rice University,* [3]*Lowell Observatory,* [4]*U.T. Austin,* [5]*NExSci.*

2:40 PM - 3:00 PM

Ongoing campaigns to characterize the planets around main sequence stars can not directly identify the planet formation timescale. Observations of pre-main sequence T Tauri stars, however, could provide a snapshot of the early stages of planet formation. These 1-3 Myr old stars present significant challenges to traditional radial velocity (RV) surveys. The presence of large, cool star spots introduces significant RV jitter which can mimic the velocity modulation from a planetary companion.

I present a methodology for distinguishing stellar activity from true companions along with results from an ongoing multiwavelength RV survey of the Taurus-Auriga star forming region. I will discuss techniques for measuring precision RVs in the K band using CSHELL on the IRTF, measurements of our long term stability, success in recovering a known exoplanet, simulations of spot-induced RV variations, and our current prospects for characterizing the pre-main sequence planet population.

228.05 – **Discovery of Massive Brown Dwarf Companions to BAF stars in Upper Scorpius**

Sasha Hinkley[1], M. J. Ireland[2], A. L. Kraus[3], J. M. Carpenter[1], P. Tuthill[4]

[1]*California Institute of Technology,* [2]*MacQuarie University, Australia,* [3]*Institute for Astronomy, Univ. of Hawaii,* [4]*University of Sydney, Australia.*

3:00 PM - 3:10 PM

We report the results of two studies carried out at the W. M. Keck Observatory targeting the very young (5 Myr) Upper Scorpius OB Association using aperture masking interferometry. Our primary goal is the direct detection of the primordial population of planets and brown dwarfs in Upper Sco. I will present the first discovery of 6-8 brown dwarf companions in our ongoing, multi-year survey of the intermediate mass stars (spectral type B, A,and F) in this association. Our discoveries of these ~20-80 Jupiter mass objects provide crucial initial characteristics of very young systems serving as a key benchmark against which evolutionary models can be compared. Moreover, this study serves as a crucial bridge between the radial velocity surveys targetting these more massive spectral types, and more conventional high contrast imaging surveys geared towards placing constraints on the frequency of companions at very large orbital radii. From a mass ratio point-of-view, our discovery of these objects are analogous to the detection of planetary mass companions orbiting solar mass stars. More importantly, our detections provide data independent of extrapolations from binary star populations or radial velocity measurements. If time permits, I will briefly mention another study targetting a sample of mid-M dwarfs in Upper Sco. These objects have Spitzer IRAC/MIPS observations confirming the presence of circumstellar debris disks in which the inner disk has been depleted of small dust grains. We can easily rule out any stellar companions or brown dwarfs as responsible for clearing the inner regions of these transitional disks. Given that these disks also show signs of dynamical stirring, we conclude the inner holes are likely sculpted by planetary mass companions,and we place an upper limit of ~10 Jupiter masses on these planets.

228.07 – **The TERMS Project: More Than Just Transit Exclusion**

Stephen R. Kane[1], Transit Ephemeris Refinement and Monitoring Survey(TERMS)

[1]*NASA Exoplanet Science Institute, Caltech.*

3:20 PM - 3:30 PM

The field of exoplanets has rapidly expanded from the exclusivity of exoplanet detection to include exoplanet characterization. Even so, studies of internal structure and atmospheres have been largely restricted to the low-periastron distance regime due to the bias inherent in the geometric transit probability. Monitoring known radial velocity planets at predicted transit times is a proven method of detecting transits, and presents an avenue through which to explore the mass-radius relationship of exoplanets at long periods around bright host stars. Here we present new results from the Transit Ephemeris Refinement and Monitoring Survey (TERMS) which provide greater insight into the dynamics of several interesting exosystems.

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229 – Evolution of Galaxies IV

Oral Session – Room 19A – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

229.01 – **The UVJ Selection of Quiescent and Star Forming Galaxies: Separating Early and Late-Type Galaxies and Isolating Edge-on Spirals**

Shannon Patel[1], B. P. Holden[2], D. D. Kelson[3], M. Franx[1], A. van der Wel[4], G. D. Illingworth[2]

[1]*Leiden University, Netherlands,* [2]*University of California, Santa Cruz,* [3]*Carnegie,* [4]*Max-Planck-Institut für Astronomie, Germany.*

2:00 PM - 2:10 PM

We utilize for the first time HST ACS imaging to examine the structural properties of galaxies in the rest-frame U-V versus V-J diagram (i.e., the UVJ diagram) using a sample at 0.6&ltz&lt0.9 that reaches a low stellar mass limit (log M/Msun&gt10.25). The use of the UVJ diagram as a tool to distinguish quiescent galaxies from star forming galaxies (SFGs) is becoming more common due to its ability to separate red quiescent galaxies from reddened SFGs. Quiescent galaxies occupy a small and distinct region of UVJ color space and we find most of them to have concentrated profiles with high Sersic indices (n&gt2.5) and smooth structure characteristic of early-type systems. SFGs populate a broad, but well-defined sequence of UVJ colors and are comprised of objects with a mix of Sersic indices. Interestingly, most UVJ-selected SFGs with high Sersic indices also display structure due to dust and star formation typical of the n&lt2.5 SFGs and late-type systems. Finally, we find that the position of a SFG on the sequence of UVJ colors is determined to a large degree by the mass of the galaxy and its inclination. Systems that are closer to edge-on generally display redder colors and lower [OII] 3727 luminosity per unit mass as a consequence of the reddening due to dust within the disks. We conclude that the two main features seen in UVJ color space correspond closely to the traditional morphological classes of early and late-type galaxies.

229.02D – **The Prevalence and Properties of Outflowing Galactic Winds at z = 1**

Katherine Kornei[1]

[1]*UCLA.*

2:10 PM - 2:30 PM

We present new results on the regulation of star formation in galaxies, specifically the study of outflowing galactic-scale winds at z = 1. With the goal of understanding how the prevalence and properties of outflows are correlated with the stellar populations of their host galaxies, we use the DEEP2 redshift survey to isolate a subsample of 72 objects in the Extended Groth Strip (EGS) for follow-up LRIS spectroscopy. These new observations, probing near-UV FeII and MgII resonance absorption lines, enable an estimate of wind velocities from the blueshifts of FeII relative to [OII] emission tracing the systemic velocity. We find that 40% of the sample exhibits significant outflows as traced by FeII absorption, possibly calling into question the ubiquity of galactic winds among z = 1 star-forming galaxies reported previously by other authors. At the same time, in a small fraction of the sample, we observe redshifted FeII features. This signature of infalling gas may be evidence for cosmological accretion, a process present in theoretical models but thus far unconfirmed by observations. With the extensive ancillary data sets associated with the EGS, we use GALEX-derived star-formation rates and HST imaging to investigate how outflows are correlated with star-formation rate, star-formation rate surface density, morphology, and inclination. We find the strongest correlation with star-formation rate surface density, where objects with higher star-formation rate surface densities exhibit stronger outflows. We also observe that face-on galaxies exhibit stronger outflows than edge-on systems, consistent with the canonical picture of winds emanating perpendicular to galactic disks. The MgII doublet at 2800 A and numerous fine-structure FeII* emission features are also observed in our LRIS spectra, offering independent probes of wind kinematics and circumgalactic gas in star-forming galaxies.

229.03 – **Carnegie-Spitzer-IMACS Survey: Following the End of Star Formation in Massive Galaxies Since z=1**

Daniel Kelson[1], R. Williams[1], A. Dressler[1], P. McCarthy[1], J. Mulchaey[1], A. Oemler[1], S. Shectman[1]

[1]*Carnegie Inst. of Washington.*

2:30 PM - 2:40 PM

The Carnegie-Spitzer-IMACS (CSI) Survey, currently underway at Magellan and NOAO, couples low-resolution optical spectroscopy with broadband near- and mid-IR photometry to obtain redshifts, masses, and emission line fluxes massive galaxies out to z~1.4. When complete, CSI will include over 10^5 3.6 micron-selected galaxies over 15 deg^2 in 3 extragalactic fields, providing an unprecedented mass-selected galaxy sample over a volume comparable to SDSS. Since targets are selected in the rest-frame near-IR, CSI is highly complete to relatively low masses for both blue and red galaxies,

making it ideally suited for studies of the mass buildup in galaxies, the shutdown of star formation, and the rise of galaxy groups over the past 10 Gyr.

Here we present initial results on the quiescent fraction of massive galaxies since z~1. By using empirically- and theoretically-motivated UVJ rest-frame color selection, we reliably separate star-forming from non-star-forming galaxies. In particular, we focus on the dependence of star-forming fraction on environment, tracing its evolution in both groups and the low-density field, in order to determine the importance of the group environment on the decline of cosmic star formation from z=1-0.

229.04 – **Carnegie-Spitzer-IMACS Survey: The Rise of Galaxy Groups Since z=1**

Rik J. Williams[1], D. Kelson[1], A. Dressler[1], P. McCarthy[1], J. Mulchaey[1], A. Oemler Jr.[1], S. Shectman[1]

[1]*Carnegie Observatories.*
2:40 PM - 2:50 PM

We present the first measurements of the evolution of the group stellar mass function (GSMF) since z=1 from the Carnegie-Spitzer-IMACS (CSI) Survey. CSI combines robust mass selection through Spitzer 3.6-micron photometry with low-resolution spectroscopy over a 15 deg^2 area, allowing the detailed study of large group (and group/field galaxy) samples over the expected epoch of group formation. From the initial 36,000 CSI galaxy redshifts over 5 deg^2, we select groups using a standard friends-of-friends algorithm in angular and redshift space, constructing the GSMF in 3 redshift bins. These mass functions agree well with GSMFs from SDSS at z=0, and with X-ray-selected cluster mass functions at higher masses and redshifts. At all masses the GSMF evolves strongly from z=0.5-1, but only weak evolution is seen in low-mass (log M* ~ 12.0) groups since z=0.5, indicating that most of these were in place at that epoch. As the majority of low-redshift galaxies reside in groups, the group environment may therefore play an important role in the decline in star formation and evolution of galaxy structures since z=1.

229.05D – **The Mass-Metallicity Relation At z~1.5 For A Sample Of Lensed Galaxies**

Eva Wuyts[1], J. R. Rigby[2], K. Sharon[3], M. D. Gladders[1]

[1]*The University of Chicago,* [2]*NASA Goddard,* [3]*University of Michigan.*
2:50 PM - 3:10 PM

We present the relation between stellar mass and gas-phase metallicity for a sample of 11 lensed galaxies at a median z=1.50+/-0.55. They are selected from the uniform, complete sample of >150 lensed sources we recently identified from a systematic survey of the SDSS DR7 (Gladders et al. 2011, in preparation). We derive stellar masses from the rest-frame UV to near-IR spectral energy distributions (SED) and metallicities from the [N II]/Hα ratio as observed with Keck/NIRSPEC. Star formation rates (SFR) are estimated both from the dust-corrected Hα flux and from the SED model. Adding data on additional lensed galaxies from the literature, we investigate the shape and scatter of the fundamental metallicity relation between stellar mass, metallicity and SFR (Mannucci et al. 2010) for individual star-forming galaxies at z~1.5, down to intrinsically lower stellar masses and SFRs than can generally be probed by non-lensed samples.

229.06 – **Herschel/hermes: Bivariate UV/IR Luminosity Functions At Z~1.5**

Sebastien Heinis[1], V. Buat[1], M. Bethermin[2], O. Ilbert[1]

[1]*Laboratoire d'Astrophysique de Marseille, France,* [2]*Institut d'Astrophysique Spatiale, France.*
3:10 PM - 3:20 PM

We study the infrared properties of a sample of ultraviolet (UV) selected galaxies at z~1.5. Using stacking at 250um, 350um and 500 um from the SPIRE imaging of the COSMOS field obtained within the HerMES key program, we derive the mean total infrared luminosity as a function of UV luminosity and slope of the UV continuum. The infrared to UV luminosity ratio does not depend on UV luminosity in the range 5×10^9 <LFUV<5×10^{10} L_{sun}, and the results also suggest that it increases at lower luminosities. We also find that the infrared to UV luminosity ratio is indeed correlated with the UV slope. Using these results we reconstruct the total far infrared (TIR) luminosity function of our UV selected sample. We discuss there results in terms of cosmic star formation rate estimation.

229.07 – **A Revised Parallel-Sequence Galaxy Classification: Structure and Formation of S0 and Spheroidal Galaxies**

John Kormendy[1], R. Bender[2]

[1]*Univ. of Texas,* [2]*Max-Planck-Institute for Extraterrestrial Physics, Germany.*
3:20 PM - 3:30 PM

We update van den Bergh's (1976, ApJ, 206, 883) parallel sequence galaxy classification in which S0 galaxies form a sequence S0a-S0b-S0c that parallels the sequence Sa-Sb-Sc of spiral galaxies. The ratio B/T of bulge to total light defines the position of a galaxy in this tuning fork diagram. Our classification makes one main improvement. We extend the S0a-S0b-S0c sequence to spheroidal (Sph) galaxies that are positioned in parallel to irregular galaxies in a similarly extended Sa-Sb-Sc-Im sequence. This provides a natural home for spheroidals, which previously were thought to be low-surface-brightness ellipticals. To motivate our juxtaposition of spheroidals and irregulars, we present photometry and bulge-disk decompositions of late-type S0s that bridge the gap between the more common S0b and Sph galaxies. We find several S0s in the Virgo cluster that have B/T <= 0.1. They are the S0cs that were missing from van den Bergh's paper. We update the structural parameter correlations of Sph, spiral and irregular, and elliptical galaxies. We show that spheroidals of increasing luminosity form a continuous sequence with the disks (but not bulges) of S0c-S0b-S0a galaxies. Remarkably, this Sph-S0-disk sequence is almost identical to that of irregular and spiral galaxies. We suggest that spheroidal galaxies are transformed, "red and dead" Scd-Im galaxies in the same way that many S0 galaxies are transformed, red and dead Sa-Sc spiral galaxies. Plausible transformation processes include ram-pressure gas stripping, gravitational harassment, and starvation by cutting off the late infall of cold gas. We suggest that many different processes act together to engineer S0 and Sph galaxies.

This work was supported by NSF grant AST-0607490.

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230 – Stellar Evolution, Stellar Populations

Oral Session – Room 19B – Tuesday, January 10, 2012, 2:00 PM - 3:30 PM

230.01 – **The GMOS Lithium-rich Giant Survey in M22**

Steven J. Margheim[1]

[1]*Gemini Observatory, Chile.*
2:00 PM - 2:10 PM

Approximately 1-2% of field K-giants have lithium abundances in excess of their expected low, diluted abundance. These Li-rich giants represent a challenge for standard stellar evolution, and several possibilities have been suggested, including giant planet ingestion and lithium production following the first dredge-up. Globular clusters are ideal laboratories for investigation of the li-rich giant phenomenon given the large number of giant members and relatively simple stellar populations. However, owing to the low incident rate and difficulty of observation, there are only few Li-rich giants known in globular clusters. The GMOS instrument at Gemini is an ideal Li-rich giant survey machine. Using a novel instrument setup, the spectrograph is capable of obtaining moderate resolution (R~8500) spectra of nearly 300 targets per field in modest amounts of time. I will present the initial results of my experimental survey of nearly 600 giants in M22.

230.02 – **GALEX Color Magnitude Diagrams for 40 Galactic Globular Clusters**

Ricardo P. Schiavon[1], E. Dalessandro[2], S. T. Sohn[3], R. T. Rood[4], R. W. O'Connell[4], F. R. Ferraro[2], B. Lanzoni[2], G. Beccari[5], S. Rey[6], J. Rhee[1], R. Rich[7], S. Yoon[8], Y. Lee[8]

[1]*Gemini Observatory,* [2]*Universita degli Studi di Bologna, Italy,* [3]*Space Telescope Science Institute,* [4]*University of Virginia,* [5]*European Southern Observatory, Germany,* [6]*Chungnam National University, Korea, Republic of,* [7]*University of California, Los Angeles,* [8]*Yonsei University, Korea, Republic of.*
2:10 PM - 2:20 PM

We present GALEX color-magnitude diagrams (CMDs) for 40 Galactic globular clusters obtained during 3 GALEX observing cycles between 2004 and 2008. This is the largest homogeneous data set ever collected on the ultra-violet (UV) photometric properties of Galactic globular clusters. We show that the horizontal branch (HB) is the dominant feature of the UV CMDs of old Galactic globular clusters. The sample spans a wide range of metallicity and HB morphology, displaying the remarkable variety of HB shapes found in old stellar populations. Blue stragglers and post core-He burning stars are other stellar types detected in our photometry. The locus in the UV CMDs of the rare post core-He burning stars in globular clusters is established. This is a legacy data set that we expect will help promoting further understanding of the evolution of low-mass stars after the Helium flash.

230.03D – **Mass-loss From Evolved Stellar Populations In The Large Magellanic Cloud**

David Riebel[1]

[1]*Johns Hopkins University.*
2:20 PM - 2:40 PM

I have conducted a study of a sample of ~30,000 evolved stars in the Large Magellanic Cloud (LMC) and ~6,000 in the Small Magellanic Cloud (SMC), covering their

variability, mass-loss properties, and chemistry.

The initial stages of of my thesis work focused on the infrared variability of Asymptotic Giant Branch (AGB) stars in the LMC. I determined the period-luminosity (P-L) relations for 6 separate sequences of ~30,000 evolved star candidates at 8 wavelengths, as a function of photometrically assigned chemistry, and showed that the P-L relations are different for different chemical populations (O-rich or C-rich). I also present results from the Grid of Red supergiant and Asymptotic giant branch star ModelS (GRAMS) radiative transfer (RT) model grid applied to the evolved stellar population of the LMC. GRAMS is a pre-computed grid of RT models of RSG and AGB stars and surrounding circumstellar dust. Best-fit models are determined based on 12 bands of photometry from the optical to the mid-infrared. Using a pre-computed grid, I can present the first reasonably detailed radiative transfer modeling for tens of thousands of stars, allowing me to make statistically accurate estimations of the carbon-star luminosity function and the global dust mass return to the interstellar medium from AGB stars, both key parameters for stellar population synthesis models to reproduce. In the SAGE-Var program, I used the warm Spitzer mission to take 4 additional epochs of observations of ~7500 AGB stars in the LMC and SMC. These epochs, combined with existing data, enable me to derive mean fluxes at 3.6 and 4.5 microns, that will be used for tighter constraints for GRAMS, which is currently limited by the variability induced error on the photometry. This work is support by NASA NAG5-12595 and Spitzer contract 1415784.

230.04D – **The Star Formation & Chemical Evolution Timescales of Two Nearby Dwarf Spheroidal Galaxies**

Thomas de Boer[1], E. Tolstoy[1], V. Hill[2], A. Saha[3], K. Olsen[3], E. Starkenburg[1], M. Irwin[4], G. Battaglia[5]

[1]*Rijks Universiteit Groningen, Netherlands,* [2]*Observatoire de la Cote d'Azur, France,* [3]*NOAO,* [4]*Institute of Astronomy, University of Cambridge, United Kingdom,* [5]*European Southern Observatory, Germany.*

2:40 PM - 3:00 PM

We present wide-field photometry of resolved stars in the nearby Sculptor and Fornax dwarf spheroidal galaxies, going down to the oldest Main Sequence Turn-Off. The accurately flux calibrated wide-field Colour-Magnitude Diagrams are used directly in combination with spectroscopic metallicities of individual RGB stars to constrain the ages of different stellar populations, and derive the Star Formation History with particular accuracy.

The Sculptor dSph contains a predominantly ancient stellar population (>10 Gyr old), which can easily be resolved into individual stars. A galaxy dominated by an old population provides a clear view of ancient processes of galaxy formation unimpeded by overlying younger populations. The Fornax dSph is dominated by stellar populations of intermediate and young ages, which can be used to study the processes of galaxy formation in a more complex mix of stellar populations

We find that the known metallicity gradients are well matched to an age gradient. This is the first time that this link with age has been directly quantified. The detailed Star Formation History shows the distribution of age with regards to the metallicity for different radii out from the centre of the galaxy.

By linking the obtained SFH to observed spectroscopic abundances (alpha-elements, r- and s-process elements) of RGB stars it is possible to put ages on the chemical evolution patterns observed in this galaxy. In this way we can study the timescale of chemical evolution in these two dwarf galaxies. By comparing both dwarfs we determine whether the chemical abundance patterns seen in galaxies with recent episodes of star formation are a direct continuation of those with only old populations.

230.05D – **The resolved stellar populations of M32**

Antonela Monachesi[1]

[1]*University of Michigan.*

3:00 PM - 3:20 PM

M32 is a compact, low-luminosity elliptical galaxy, satellite of M31. Given its proximity, M32 can be studied in great detail not only from its integrated spectrum but also from its resolved stars in a way that is impossible for most of the elliptical galaxies. However, the star formation history of M32 is still a matter of debate. Moreover, there has not been a consistent comparison between predictions from the spectroscopic analysis of its integrated light and its resolved stellar content.

In this talk, I will present the most complete inventory yet possible of the resolved stellar populations of M32 and its star formation history at 2 arcmin from its center, from both qualitative and statistical analyses of deep color-magnitude diagrams. Very high-resolution HST observations of two fields near M32 were used to construct and analyze the deepest color-magnitude diagram of M32 to date. We find that M32 has had an extended star formation history and is composed of two main dominant populations: a 2-5 Gyr old, metal-rich population and a population older than 5 Gyr, with slightly subsolar metallicities. These results not only significantly improve our knowledge on the stellar populations of M32 but also provide an unprecedented rich data base to compare with unresolved stellar population models and to test their applicability to more distant galaxies.

230.06 – **Discovery of Super-Lithium Rich Red Giants in Milky Way Satellite Galaxies**

Evan Kirby[1], X. Fu[2], P. Guhathakurta[3]

[1]*California Institute of Technology,* [2]*National Astronomical Observatories of China, China,* [3]*UC Santa Cruz.*

3:20 PM - 3:30 PM

The convective envelopes of evolved red giants reach temperatures of millions of K, hot enough to destroy lithium. Very few red giants more luminous than the luminosity function bump display any detectable lithium. Nonetheless, we found 13 lithium-rich red giants among a sample of 2961 red giants in Milky Way dwarf satellite galaxies. The abundances range from $A(\mathrm{Li}) = 2.15$ to 4.27. Nine of the stars have lithium abundances higher than the primordial value. Therefore, the lithium in these stars must have been created rather than saved from destruction. The ages of most of these galaxies suggest that the lithium was produced in the red giants themselves rather than mass transfer from intermediate-mass asymptotic giant branch stars.

231 – Pierce Prize: Who is Under the HAT? Small Telescopes Yield Big Science

Invited Session – Ballroom D – Tuesday, January 10, 2012, 3:40 PM - 4:30 PM

231.01 – **Pierce Prize: Who is Under the HAT? Small Telescopes Yield Big Science**

Gaspar Bakos[1]

[1]*Harvard-Smithsonian Center for Astrophysics.*

3:40 PM - 4:30 PM

Astronomy with small telescopes has experienced a renaissance over the past decade. In this talk I will advocate small telescope astronomy in general, and focus in particular on one such project which I am heavily involved in. The HATNet survey uses 10 centimeter 'telescopes' to discover extrasolar planets which transit their host stars at regular intervals, blocking a small fraction of the stellar light as they do so. Candidate planets are initially identified using these small telescopes, and then confirmed using 1 and 10 meter class telescopes. To date our survey has discovered several dozen planets in this manner. During my talk I will describe the entire procedure leading to these discoveries. The transiting nature of these systems provides an opportunity to gain a deep insight into their astrophysics. Just some of the wealth of scientific results which come out of these systems, which I will describe, include measurements of the planetary masses, radii and equilibrium temperatures, the alignment between the planetary orbit and the stellar spin axis, the composition of the planetary atmospheres, the existence of perturbing planets or moons, and precisely measured parameters for the host stars. These new worlds exhibit an amazing diversity, and surprising correlations between some of the physical parameters, having important consequences for theories of planet formation and evolution.

232 – Catching Up: Theory in a Decade of Transiting Exoplanets

Invited Session – Ballroom D – Tuesday, January 10, 2012, 4:30 PM - 5:20 PM

232.01 – **Catching Up: Theory In A Decade Of Transiting Exoplanets**

Dimitar D. Sasselov[1]

[1]*Harvard-Smithsonian CfA.*

4:30 PM - 5:20 PM

Observations have led the way in discovery and exploration of planets orbiting other stars, often surprising and puzzling planetary and stellar theorists. They are challenging preconceptions about disks and formation, orbits and architecture, planets and structure, and what defines a planet like Earth. We are able to see our own solar system from a different perspective. I will review that new perspective with emphasis on three topics: theory of planet formation, theory of planet structure, and life as a planetary phenomenon.

233 – HEAD Business Meeting

Town Hall – Room 18B – Tuesday, January 10, 2012, 5:30 PM - 6:30 PM

Annual business meeting of the High Energy Astrophysics Division.

234 – NRAO Town Hall

Town Hall – Ballroom E – Tuesday, January 10, 2012, 6:30 PM - 8:30 PM

This Town Hall will inform the AAS membership about the status of the National Radio Astronomy Observatory (NRAO) science and science operations, observatory development and programs, and construction projects. The NRAO Town Hall will open with a reception that will be followed by brief presentations designed to update the membership regarding: (a) science opportunities and construction status at the Atacama Large Millimeter/submillimeter Array (ALMA) and the Expanded Very Large Array (EVLA); (b) science opportunities and development programs at the Green Bank Telescope (GBT) and the Very Long Baseline Array (VLBA); (c) recent science results from across the 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 – Heineman Prize: Exploding Stars and the Accelerating Universe

Invited Session – Ballroom D – Wednesday, January 11, 2012, 8:30 AM - 9:20 AM

300.01 – **Exploding Stars and the Accelerating Universe**

Robert P. Kirshner[1]

[1]*Harvard-Smithsonian CfA.*

8:30 AM - 9:20 AM

Supernovae are exceptionally interesting astronomical objects: they punctuate the end of stellar evolution, create the heavy elements, and blast the interstellar gas with energetic shock waves. By studying supernovae, we can learn how these important aspects of cosmic evolution take place. Over the decades, we have learned that some supernovae are produced by gravitational collapse, and others by thermonuclear explosions.

By understanding what supernovae are, or at least learning how they behave, supernovae explosions have been harnessed for the problem of measuring cosmic distances with some astonishing results. Carefully calibrated supernovae provide the best extragalactic distance indicators to probe the distances to galaxies and to measure the Hubble constant.

Even more interesting is the evidence from supernovae that cosmic expansion has been speeding up over the last 5 billion years. We attribute this acceleration to a mysterious dark energy whose effects are clear, but whose nature is obscure. Combining the cosmic expansion history traced by supernovae with clues from galaxy clustering and cosmic geometry from the microwave background has produced today's standard, but peculiar, picture of a universe that is mostly dark energy, braked (with diminishing effect) by dark matter, and illuminated by a pinch of luminous baryons.

In this talk, I will show how the attempt to understand supernovae, facilitated by ever-improving instruments, has led to the ability to measure the properties of dark energy.

Looking ahead, the properties of supernovae as measured at infrared wavelengths seem to hold the best promise for more precise and accurate distances to help us understand the puzzle of dark energy. My own contribution to this work has been carried out in joyful collaboration with many excellent students, postdocs, and colleagues and with generous support from the places I have worked, the National Science Foundation, and from NASA.

334 – The Solar System

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

334.01 – **When Oort Clouds Collide**

Catherine Gosmeyer[1], S. Levine[2]

[1]*Indiana University,* [2]*Lowell Observatory.*

9:00 AM - 6:30 PM

If other stars have Oort clouds similar to that theorized for the Sun (roughly spherical, with a radius of 100,000 AU), could the clouds interact during a close stellar passage and transfer material? How likely is it that the Sun's Oort cloud contains comets stripped from other stars' clouds?

We modeled encounters between the Oort clouds of the Sun and passing stars over four billion years. Our simulations showed that over the Sun's lifetime, it would have many encounters resulting in some mass exchange and a handful of encounters resulting in large mass exchange.

At least 5% of the Sun's comet population might be from other stars, and potentially much more. The range of mass gained (or lost) integrated over the ensemble of encounters is quite wide.

Even in encounters that did not result in exchange of comets in the clouds, our simulations showed that they can still pump up the eccentricity of the orbits of some of the comets into highly elliptical orbits. A few comets gain eccentricities close enough to one to bring them into the inner Solar System, consistent with the observed orbits of hyperbolic and very long period comets.

Acknowledgments: CMG was supported by the NAU REU program (funded by NSF, grant number AST-1004107).

334.02 – **Lsst As A New Probe Of The Oort Cloud**

Michael Solontoi[1], N. Kaib[2]

[1]*Adler Planetarium,* [2]*Queen's University, Canada.*

9:00 AM - 6:30 PM

The current catalog of long-period comets (LPCs) is overwhelmingly dominated by cometary orbits passing within a few AU of the Sun. By the time LPCs reach such low perihelia, it is very likely their orbital semimajor axes have already been strongly modified by planetary perturbations (Kaib & Quinn 2009). Consequently, the present sample of LPCs offers little constraint on the true orbital structure of the Oort Cloud. Detecting LPCs with larger perihelia will place significantly better constraints on Oort Cloud structure, and LSST offers the best prospect to build such a cometary catalog in the near future. Using numerically simulated comet orbits coupled with observationally motivated models for LPC magnitudes and the LSST observational cadence (Solontoi et al. 2011), we estimate the perihelion range that LSST will be able to efficiently detect long-period comets.

334.03 – **Searching for Faint Kuiper Belt Objects in HST Archival Data**

Daniel Feldman[1], C. Fuentes[2], D. Trilling[2]

[1]*College of Staten Island,* [2]*Northern Arizona University.*

9:00 AM - 6:30 PM

We present an automated method for detecting faint Kuiper Belt Objects (KBOs) in archival HST/ACS data. We developed a software infrastructure that is flexible and can be used to manage large datasets of archival data for numerous projects, and requires no interaction with a human operator. With this infrastructure, as well as previously developed software for HST data analysis, we hope to detect KBOs with R < 50km and have rapid follow-up and recovery of the detected KBOs for further study. Preliminary results have suggested we can detect 1 KBO per ~10 datasets of HST archival data. This work was supported through the NSF Research Experience for Undergraduates Program at Northern Arizona University.

334.04 – **Identification, Calculation Of The Three Dimensional Orbit, And Flux Of Asteroid 2007 TD14**

Vincent Pereira[1], E. Martin[2], J. Millan[2]

[1]*Freeport Public Schools,* [2]*Freeport High School.*

9:00 AM - 6:30 PM

In recent years the rate of discovery of asteroids has improved dramatically and has far outstripped efforts to physically characterize them. In this work, we took part in the International Astronomical Search Campaign and confirmed the discovery of asteroid 2007 TD14. We then calculated the two and three dimensional orbit of the asteroid around the sun, given its six elements of orbit. Once the heliocentric and geocentric distances are known, and the visual magnitude of the asteroid obtained through photometry, its diameter can be calculated assuming a suitable value for the albedo. The diameter was 0.718 km and the albedo was 0.039. Using the Standard Thermal Model we calculated the temperature distribution on the surface of the asteroid and the flux of the asteroid in the thermal infrared (1.095 mJy at 22 microns on March 19, 2010). To the best of our knowledge there have been no previous reports of the diameter and flux of the asteroid. Our ultimate goal is to compare our flux values with newly released data from NASA Wide-field Infrared Survey Explorer Mission and thus obtain better estimates of the asteroid diameter and albedo.

334.05 – **Overview of Asteroid Threat Mitigation Activities at LLNL**

Kirsten Howley[1], T. Antoun[1], D. Dearborn[1], J. Elliott[1], S. Gibbard[1], E. Herbold[1], I. Lomov[1], R. Managan[1], A. Miles[1], P. Miller[1], M. Owen[1], J. Wasem[1], O. Vorobiev[1]

[1]*Lawrence Livermore National Laboratory.*
9:00 AM - 6:30 PM

Asteroid or comet collisions with Earth represent a low-probability but potentially very high-consequence threat. Effects of such collisions range from localized disasters to massive global devastation. One of the principal difficulties in assessing impact hazards from near-Earth objects (NEOs) is the diversity of the threat. Potentially hazardous objects (PHOs) range from 30-meter diameter asteroids, to 5-kilometer comets, including a range of compositions, shapes, densities, and a variety of types of orbits. As an initial step, we are developing scenarios that span a range of threat compositions, sizes, dynamics and times to impact. We intend to investigate these various scenarios in order to optimize deflection options and examine potential breakup of PHOs. We propose these scenarios as an initial starting point for consideration, and solicit feedback and comments from experts in the field.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-503211.

334.06 – **Classification of Asteroid 9983 Rickfienberg using Spectral Photometry**

Coty Tatge[1], D. Arion[1], R. Fienberg[2]

[1]*Carthage College,* [2]*American Astronomical Society.*
9:00 AM - 6:30 PM

Asteroid 9983 has not yet been previously classified. The asteroid was classified using spectral photometry. Images were obtained using the 0.9-meter WIYN telescope at Kitt Peak Observatory, the S2KB camera, and U, B, V, R, and I Harris filters. Landolt reference stars were used to calibrate the imaging system. These observations were conducted in parallel with observations being made at Andover Academy to determine a rotational lightcurve. These observations were well timed to occur during the recent opposition of 9983 Rickfienberg. This work was supported in part by the Wisconsin Space Grant Consortium and a private bequest from Ms. Linda Staubitz.

334.07 – **Lunar Reconnaissance Orbiter (LRO) Lyman Alpha Mapping Project (LAMP) Maps of the Permanently Shaded Regions (PSR) at the Lunar Poles**

Amanda J. Bayless[1], K. D. Retherford[1], G. R. Gladstone[1], S. A. Stern[2], A. F. Egan[2], P. F. Miles[1], J. W. Parker[2], D. E. Kaufmann[2], D. G. Horvath[1], T. K. Greathouse[1], M. H. Versteeg[1], A. J. Steffl[2], J. Mukherjee[1], M. W. Davis[1], D. C. Slater[1], P. M. Rojas[1], P. D. Feldmann[3], D. M. Hurley[4], W. R. Pryor[5], A. R. Hendrix[6]

[1]*Southwest Research Institute, San Antonio,* [2]*Southwest Research Institute, Boulder,* [3]*John Hopkins University,* [4]*John Hopkins University, Applied Physics Labs,* [5]*Central Arizona University,* [6]*Jet Propulsion Laboratory.*
9:00 AM - 6:30 PM

The Lunar Reconnaissance Orbiter (LRO) was launched on June 18, 2009 and is currently in a polar orbit. The Lyman Alpha Mapping Project (LAMP) instrument on-board LRO is a UV spectrograph covering the spectral range of 57-196 nm. Its 6 deg x 0.3 deg slit is arranged in push-broom mode to collect photon events in time ordered pixel-list mode, which allows reconstruction of exquisite 240m/pixel far-UV maps. The instrument sensitivity is optimized for faint nightside and PSR reflectivity measurements, requiring use of a pinhole aperture during dayside viewing. We present Lyman-alpha and far-UV albedo maps of the north and south poles with comparisons to topographic and other LRO datasets. These maps indicate that the coldest, permanently shadowed regions (PSR) in deep polar craters have significantly lower Lyman-alpha albedo than the surrounding regions, which is best explained by a high surface porosity there - possibly related to the accumulation of volatile frosts. Spectral ratios at longer far-UV wavelengths suggest that water frost is accumulated on the surface of certain PSRs at 1-2% abundance.

334.08 – **Analysis Of The Morphology Of Comets Using Photometry: C/2009P1 Garrad And P1/Halley**

Herbert Mehnert[1], J. Cline[2], M. Castelaz[3]

[1]*Massachusetts Institute of Technology,* [2]*Pisgah astronomical Research Institute,* [3]*Pisgah Astronomical Research Institute.*
9:00 AM - 6:30 PM

The surface brightness distribution of comet C/2009 P1

Garrad was studied to identify structure and fragmentation within the nucleus of the comet. Surface brightness mapping was done by performing pixel by pixel photometry on images taken of the comet taken in July 2011 using the PARI 0.35-m prime focus telescope. Comet Garrad's surface brightness maps are compared to those of 1P/Halley (1986) obtained from digitized images from Dyer Observatory photographic plates. That ollection of plates are now located in the PARI Astronomical Photographic Data Archive. Through the technique of pixel by pixel photometry and surface brightness mapping, comet nuclei may be studied more fully than by pure imaging, and some of the difficult to image structure of comet nuclei may be revealed. Results will presented that show that the nucleus of C/2009/P1 Garrad is a single elongated object. However, it has the indications of possible future fragmentation as seen in the brightness maps of the comet.

334.10 – **The Phase Function of Main-Belt Comet P/2008 R1 (Garradd)**

Eric M. MacLennan[1], H. Hsieh[2]

[1]*Northern Arizona University,* [2]*Institute for Astronomy.*
9:00 AM - 6:30 PM

We present observations of the Main-Belt Comet P/2008 R1 (Garradd) allowing the study of the object's phase function. Main-Belt Comets are characterized as having orbits indistinguishable from main-belt asteroids and exhibiting cometary activity. While inactive, images of Garradd were taken by the Gemini North telescope atop Mauna Kea allowing us to measure the absolute magnitude $H_R = 20.3 \pm 0.1$ mag and slope parameter $G = 0.08 \pm 0.05$ used in the IAU phase function. Assuming an R-band albedo of $p_R = 0.05$ we determine an effective radius of $r_N \approx 0.22$ km. Knowledge of the phase function and radius allows us to look at 2008 observations of Garradd when it was active and quantify dust mass loss.

334.11 – **The Influence of Giant Planet Mass on Long-Period Comet Flux**

Alexia Lewis[1], T. Quinn[1]

[1]*University of Washington.*
9:00 AM - 6:30 PM

We study the effect of the outer solar system architecture on the flux of Earth-crossing comets. In particular, we seek to quantify the role of the giant planets as ``planetary protectors''. Because the outer planets modify the structure of the Oort Cloud throughout its formation, we must follow its evolution over the full age of the solar system. We have run simulations in each of 4 different planetary mass configurations to analyze the structure and formation of each Oort Cloud and to better constrain the flux of comets into the inner solar system. Particles are integrated over 4.5 Gyrs under the influence of the giant planets, the Galactic tide, and passing stars. We find that the structure of the Oort Cloud, including the location of boundaries and the relative number of comets in the inner and outer Oort Cloud, does not change significantly between configurations. As overall planetary mass decreases, the flux of comets increases. Trapping efficiency of the Oort Cloud also increases, as expected. We find that Saturn is as effective as Jupiter at deflecting possible Earth-crossing comets, as reflected by the fact that a comparable numbers of particles enter the inner solar system when we independently reduce their masses. In each configuration, we confirm the conclusion from Kaib & Quinn (2009) that the majority of observable comets originate in the inner Oort Cloud. Although the final effect may be small, accounting for the formation and growth of the giant planets in simulations may help us better understand the trapping efficiency of the Oort Cloud and the mass of the protoplanetary disk.

334.12 – **A Comparison of 2D and 3D RAGE Hydrocode Simulations of Effective Mitigation of Porous PHO Objects**

Robert Weaver[1], W. Dearholdt[1]

[1]*LANL.*
9:00 AM - 6:30 PM

In this paper we show 2D and 3D simulations from a validated hydrocode (RAGE) of the effects of a strong explosion on the surface of a porous nonspherical asteroid like object. The composition of the simulated asteroid is made more realistic than previous work by using a random distribution of rocks constrained by a non-spherical outer surface. These simulations can be categorized as explosion effects on "rubble pile" asteroids. The main goal of this work is to apply realistic hydrodynamics to 2D and 3D rubble pile models and examine the results to see if sufficient momentum is transferred to the porous object so as to mitigate the hazard posed by the initially Earth crossing orbit.

334.13 – **Modelling Injection of Short-Lived Radioisotopes into a Structured Pre-Solar Cloud**

Matthew D. Goodson[1], F. Heitsch[1]

[1]*UNC-Chapel Hill.*
9:00 AM - 6:30 PM

Meteorite studies indicate that active short-lived radionuclides (SLRs) were incorporated into the pre-solar cloud. A nearby supernova could have provided enrichment, but previous hydrodynamical simulations of such an event have been unable to inject sufficient amounts of SLRs. We hypothesize that sub-structure in the target molecular cloud will increase injection efficiencies. We test this hypothesis by simulating the interaction of a shock wave carrying a tracer scalar with a structured molecular cloud. We model the pre-solar cloud as collection of randomly distributed spheres ("cloudlets"). We use the Athena code in 2-D hydrodynamics with a variety of equations of state, and

we measure the fraction of ejecta carried in the shock wave that ends up in relevant cloud densities. Already this simple sub-structure increases the injection efficiency by roughly an order of magnitude. Although this is still below observed injection amounts, it offers a notable improvement. Future simulations in 3-D will employ thermal physics, gravitational potentials, and magnetohydrodynamics.

334.14 – **Investigating Chemical Compositions of Select Saturnian Satellites via Mosaicking of Cassini VIMS Observations.**

Laura Hosmer[1], C. Dalle Ore[2], R. Mastrapa[2], A. Speck[1]

[1]*University of Missouri-Columbia,* [2]*SETI Institute, NASA Ames Research Center.*
9:00 AM - 6:30 PM

Cassini has collected data of many of Saturn's moons which provide information on the surface composition of the satellites and ultimately investigate their chemical and physical history. Mosaics are vital in analyzing the large amounts of data gathered from VIMS. Programs ENVI 4.8 and ISIS 3 were utilized and their results compared to determine optimum efficiency and output when creating mosaics. It was desirable to duplicate the cluster analysis of Mimas performed by Marzo [1] to definitively prove ISIS 3's capability to create mosaics identical to ENVI. Concerning the satellites of Saturn we were interested in searching for evidence of polycyclic aromatic hydrocarbons (PAHs) as well as CO_2 via cluster analysis. Preliminary results of Mimas show that the outline of Hershel crater belongs to a different group than the immediate surroundings implicating a variation in the physical properties of the ice. Since the clustering was done focusing on a short wavelength range around the 1.5 micron water band the variation is most likely due to grain size differences as shown by Stephan et al (2005) in their study of Ganymede. The other intriguing feature outlined by the clustering of Mimas is a pattern on the side of the ring outlining the Hershel crater. The representative spectrum of this group shows an anomaly that could be due to contamination of minerals from an impact. Further analysis is necessary to confirm this preliminary result. The ultimate goal of our attempt at reproducing the mosaic independently (with ISIS3) and to repeat the cluster analysis is to investigate this intriguing result.

334.15 – **Exploring Frontal Events on Mars Using MRO MARCI Images**

Jordan D. Wheeler[1], H. Wang[2]

[1]*University of Missouri - Columbia,* [2]*AMP, SAO, Cambridge.*
9:00 AM - 6:30 PM

We have processed global map swaths taken by MRO MARCI, and made Mars Daily Global Maps (MDGMs) for the second MRO mapping year (MY 29 Ls =121 to MY 30 Ls =112). We have used our MDGMs to make a catalog of all curvilinear clouds and dust storms called "frontal events", which are analogous to the cloud pattern of a terrestrial baroclinic storm. The spatial and temporal distribution of the frontal activity is presented. They are found to be largely consistent with previous observations conducted with the Mars Global Surveyor. There are more frontal events in the northern hemisphere than in the southern hemisphere. For the northern hemisphere, there are more frontal events in spring and summer than in the fall and winter. There are seperate seasonal periods when cloud frontal events or dust frontal events dominate. There is a period around the winter solstice when frontal events are suppressed. Before and after this period there are large flushing events transporting dust to low latitudes. Spatial distribution of frontal events in the north are most prevalent in the low topographical regions, especially in Acidalia. Frontal events in the south were found to be more frequent in the anti-cryptic zone. The temporal distribution follows a latitudinal trend in relation with the changing size of the polar caps. We have examined the fine structure of frontal events, and found blotchy textures in many cases, indicating that frontal circulation can trigger active dust lifting.

334.16 – **Quantifying Uncertainties in the Evolution of the Solar Flux**

John Sheets[1], M. W. Claire[2], M. Cohen[3], I. Ribas[4]

[1]*University of Washington,* [2]*University of East Anglia, Norwich, UK, BlueMarble Space Institute of Science, University of Washington,* [3]*University of California, Berkeley,* [4]*Institut deCiències de l'Espai (CSIC-IEEC), Spain.*
9:00 AM - 6:30 PM

Understanding changes in the solar fluxover geologic timescales is essential to studies of planetary atmospheres andhow planets evolve in general. To this end, we have developed quantitativeestimates of the wavelength-dependent solar flux over time. Usingmulti-wavelength data from the Sun and solar analogs we present aparametrization of the solar flux which is nominally valid from 2-20000 nm, andfrom ~0.02 through 7.1 Gyr.

The parameterization is subject to inherent uncertainties in primary measurementerror, the unknown ages of the solar proxies, and the intrinsic variability ofthe solar analogs. This poster details our procedures in quantifying the effectof these uncertainties on our estimates of the evolving solar flux. We derivedthousands of different power law fits to the observational data via a MonteCarlo simulation that spans from the X-ray to the UV. During each iteration ofthe simulation, an age for each solar analog was selected randomly from ageranges found in the literature. These ages are fit against the observationaldata, which are themselves randomized by their measurement errors and assumedintrinsic variability. We find the integrated mean error of our Monte Carlosimulations to never be in excess of 5%, with significant decreases in error atolder stellar ages. The mean absolute error on any flux value from anywavelength is never above 25%. We therefore submit our model of the solar fluxas viable for planetary atmosphere studies that are concerned with the firstorder evolution of the Sun in time. To this end, we have implemented our solarflux estimates into a model of atmospheric chemistry of early Earth, anddescribe the changes in estimates of photolysis rates for a few key atmosphericspecies.

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335 – The BigBOSS Multi-Object Spectrograph on the Mayall Telescope

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

335.01 – **Measuring neutrino properties with BigBOSS**

Anze Slosar[1], P. McDonald[2], BigBOSS team

[1]*Brookhaven National Lab,* [2]*Lawrence Berkeley National Lab.*
9:00 AM - 6:30 PM

BigBOSS will measure cosmological fluctuations in an unprecedented volume of the Universe, covering 14000 sq.deg. and redshifts to z=3 using two complementary tracers of cosmic structure: galaxies and the Lyman-alpha forest. Using the Fisher-matrix methodology we estimate its ability to measure the neutrino mass hierarchy. Most signal comes from galaxy clustering. We should be able to measure the total mass with precision of 17meV at 1 sigma. Since terrestrial measurements of neutrino oscillations put a lower limit on the sum of netrino mass eigenstates to ~50meV, BigBOSS should detect a non-zero neutrino mass. Depending on the fiducial model assumed, it might also be able to measure neutrino mass difference or rule-out inverted hierarchy. We discuss control of the systematic effects and the potential impact of these results on neutrino physics.

335.02 – **The BigBOSS Dark Energy Figure of Merit**

Patrick McDonald[1], BigBOSS Collaboration

[1]*LBNL/BNL.*
9:00 AM - 6:30 PM

BigBOSS will make a redshift-space map of 14000 sq. deg. of sky using galaxies out to z~1.6 and quasars beyond that, producing baryon acoustic oscillation (BAO) distance measurements out to z~3.5. These measurements will improve the Dark Energy Figure of Merit (FoM) by a factor ~3 beyond Stage III experiments, comparable to any planned BAO experiment (including those in space). A further factor of 2 or more in FoM can be gained using the galaxy power spectrum beyond BAO, e.g., including redshift-space distortions and the Alcock-Paczynski test. We describe these projections and comparisons with other experiments.

335.03 – **Millions of z>0.6 Luminous Red Galaxies from BigBOSS + WISE**

Jeffrey Newman[1], T. Licquia[1], N. Mostek[2], K. Barbary[2], A. Stanford[3], A. Dey[4], J. Kneib[5], M. Levi[2], D. Schlegel[2], BigBOSS Team

[1]*U. Pittsburgh / Pitt-PAC,* [2]*LBL,* [3]*UC Davis,* [4]*NOAO,* [5]*OAMP, France.*
9:00 AM - 6:30 PM

The most luminous red galaxies (LRGs) provide an excellent tracer of large scale structure in the Universe due to their strong clustering, but they are difficult to select at z>0.6 from optical imaging alone. We demonstrate here that simple color cuts based upon SDSS r/i-band and WISE 3.4 micron photometry allow us to efficiently select $0.6 < z < 1$ LRGs while strongly rejecting stellar contaminants. This technique exploits the fact that the "1.6 micron bump" (i.e., the bolometric peak of red galaxy SEDs at 1.6 microns) lies near the center of the WISE 3.4 micron passband at z~1. We test these techniques using WISE data in fields covered by the zCOSMOS and DEEP2 survey, investigating the nature of resulting samples. Our methods select 400 candidate LRGs per square

degree, yielding more than 5 million targets over the BigBOSS footprint; 97% of the objects targeted are galaxies at z>0.55, 96% of which are on the red sequence. We also explore selection using only Palomar Transient Factory r-band imaging and WISE 3.4 micron data in the COSMOS field, finding that we can still effectively select LRGs, at the cost of a contamination with bright Emission Line Galaxies which are also of interest for BigBOSS.

335.04 – **What You Can Do with Millions of Spectra: Galaxy Evolution with BigBOSS**

Adam S. Bolton[1], G. Rudnick[2], E. F. Bell[3], BigBOSS collaboration

[1]*University of Utah,* [2]*University of Kansas,* [3]*University of Michigan.*
9:00 AM - 6:30 PM

Very large spectroscopic surveys such as the SDSS have been watersheds in our understanding of galaxy evolution. The power of these surveys is that their spectra enable astrophysical measurements while simultaneously having enough objects to explore the multivariate properties of the galaxy population. The BigBOSS instrument has the potential to become a similarly transformative tool for improving our understanding of how galaxies evolve. The BigBOSS Key Project will result in low signal-to-noise spectra for 20 million galaxies at z<1.7 over 14,000 square degrees, with one million "synchronous fibers" that are not assigned to Key Project targets and are open for community science. Calibration fields for the Key Project will provide densely sampled and deeper exposures than the main survey, over many tens of square degrees. The BigBOSS instrument itself will be a powerful PI instrument long after the Key Project is finished. It will have 5000 rapidly positioned fibers that feed a spectrograph with high throughput from 360-1040nm over a 7 square degree field of view. Here we present a sample of example community science projects that cover the range of anticipated operating modes: 1) a measure of the distribution in galaxy properties, e.g. velocity dispersion, using large numbers of well-calibrated spectra with low signal-to-noise, 2) a large extragalactic survey aimed at understanding how stars grow within dark matter halos at z<1 as a function of environment, halo mass, and galaxy star formation history, 3) A survey of the infall regions of galaxy clusters at intermediate redshift, and 4) a search for extremely rare and bright objects that may be the most intrinsically luminous galaxies in the Universe or are strongly gravitationally lensed. These examples were raised in the BigBOSS community workshop hosted by NOAO in September 2011 and can serve as an inspiration for developing community projects with BigBOSS.

335.05 – **BigBOSS - A Proposed Stage IV Baryon Acoustic Oscillation Experiment at the KPNO Mayall 4-m Telescope**

Chris Bebek[1], BigBOSS Collaboration

[1]*LBNL.*
9:00 AM - 6:30 PM

The BigBOSS Key Project is a 14,000 square degree survey that will be carried out using 500 nights over five years. Using data from imaging surveys that are already underway, we will select spectroscopic targets that trace the underlying dark matter distribution. In particular, we will measure the redshifts of luminous red galaxies (LRGs) up to z = 1:0. To probe the universe out to even higher redshift, we will target bright [OII] emission line galaxies (ELGs) up to z = 1:7. In total, approximately 20 million galaxy redshifts will be obtained to measure the BAO feature, trace the matter power spectrum at smaller scales, and detect redshift space distortions. BigBOSS represents at least an order of magnitude improvement over BOSS both in the co-moving volume it probes and the number of galaxies it will map. In addition to the cosmological constraints coming from the galaxy survey, BigBOSS will provide additional constraints on early dark energy and on the curvature of the universe by measuring the Ly-alpha forest in the spectra of over 600,000 2:2 < z < 3:5 quasars.

335.06 – **Optical Fibre Connection Performance Investigation for BigBOSS"**

Claire Poppett[1], J. Edelstein[1], M. Sirk[2], A. M. Vanderburg[2]

[1]*Lawrence Berkeley National Lab,* [2]*Silver Space Sciences Lab, UC Berkeley.*
9:00 AM - 6:30 PM

Fibre optics connectors with satisfactory performance in terms of throughput and conservation of étendue would be beneficial to many astronomical fibre optic systems. We measure the focal ratio degradation performance of various methods of fibre connections which are commercially available in order to establish a method which will meet the BigBOSS design requirements. These results are then compared to theoretical predictions in order to quantitatively evaluate their performance.

335.07 – **Integration of the BigBOSS Instrument with the Mayall 4m Telescope**

Robert Besuner[1], BigBOSS Collaboration

[1]*UC Berkeley/Space Sciences Lab.*
9:00 AM - 6:30 PM

BigBOSS is a proposed multi-object spectrograph for the Mayall 4-meter telescope at Kitt Peak. Its primary objective is to explore dark energy using the baryon acoustic oscillation method by measuring tens of millions of galaxy redshifts . The BigBOSS corrector optics and its 5000-fiber-positioner focal plane assembly will replace the existing hardware at prime focus on the Mayall telescope. The 40-meter long BigBOSS optical fiber bundle will be routed from prime focus through the telescope declination and polar pivots to the adjacent existing thermally insulated Coude Laboratory. Thirty spectrographs in three color bands will be located in the Coude Laboratory, along with associated support electronics, cooling, and vacuum equipment. The new prime focus assembly will include provisions for mounting the existing F/8 secondary mirror to allow observations with Cassegrain instruments. In our poster, we illustrate the major elements of the BigBOSS instrument and describe the proposed modifications and additions to existing Mayall facilities.

335.08 – **BigBOSS Optical System**

Michael Sholl[1], BigBOSS Collaboration

[1]*University of CA Berkeley.*
9:00 AM - 6:30 PM

BigBOSS is a proposed ground-based dark energy experiment designed to study baryon acoustic oscillations (BAO) and the growth of large scale structure through a 14,000 square degree survey of emission line galaxies, luminous red galaxies and quasi-stellar objects. The project involves design, construction and installation of a new widefield optical corrector for the Mayall 4m telescope. The corrector magnifies the f/2.81 prime focus to f/4.5 over a circular field of view of three degrees. A prism-based atmospheric dispersion compensator is included in the design, to allow broadband spectroscopy over a range of angles up to 60 degrees from zenith. A robotically positioned 5000 fiber system directs galaxy light to a remote array of 10 spectrometers, each with three channels. Optical design, fabrication, tolerances and alignment of the widefield corrector and spectrometer are discussed.

335.09 – **Thermo-Mechanical Design of the BigBOSS Prime Focus Corrector**

Paul Perry[1], C. Bebek[1], R. Besuner[2], J. Edelstein[2], P. Jelinsky[2], R. Lafever[1], C. Schenk[2], M. Sholl[2], J. Silber[1]

[1]*LBNL,* [2]*UC Berkeley Space Sciences Laboratory.*
9:00 AM - 6:30 PM

The proposed BigBOSS instrument includes a new wide field prime focus corrector and fiber-fed spectrograph for the Mayall 4m telescope at Kitt Peak, Arizona. Five thousand robotically positioned fibers in the Ø0.95m focal plate feed spectrographs that will measure the redshift of 20 million galaxies, surveying 10-20 times the volume of existing studies. To achieve the strict light throughput required for this survey the prime focus instrument must maintain tight requirements on alignment and distortion. These requirements are met though stiffness and thermal design balanced against mass and volume constraints on the existing Mayall telescope structure. In our poster we will present the mechanical design of the prime focus corrector, describe its components, and show system deflection and thermal distortion predictions.

335.10 – **Practical Spectro-Perfectionism in SDSS-III**

Stephen J. Bailey[1], A. Bolton[2], J. Brownstein[2], T. Kisner[1], P. Pandey[2], D. Schlegel[1]

[1]*LBNL,* [2]*University of Utah.*
9:00 AM - 6:30 PM

As extragalactic spectroscopic surveys push to higher redshifts, the targeted objects are fainter and fainter, yet the night-sky foreground remains as bright as ever. This requires spectral extraction algorithms to push to new limits of signal-to-noise. The "spectro-perfectionism" algorithm of Bolton & Schlegel 2010 provides a framework to achieve poisson-limited sky subtraction through the forward modeling of photons onto the spectrograph CCDs using a two dimensional point spread function. This method produces uncorrelated errors in the extracted spectra while fully preserving the input spectrum likelihood function given the raw CCD pixel data. A brute-force implementation of this algorithm would be computationally prohibitive. We present a practical implementation of this algorithm for the Baryon Oscillation Spectroscopic Survey (BOSS) of the Sloan Digital Sky Survey III (SDSS-III). This implementation handles the full complexity of real data while being computationally tractable on current-generation hardware. The gains from this implementation will increase the science reach of BOSS and will be critical for future redshift surveys such as the proposed BigBOSS project.

335.11 – **R-Theta Fiber Positioner Study For The BigBOSS Instrument**

C. Schenk[1], **Joseph H. Silber**[2], Z. Zhou[2], R. L. Post[2], M. D. Cepeda[2]

[1]*Space Sciences Laboratory (SSL), UC Berkeley,* [2]*Lawrence Berkeley National Laboratory (LBNL).*
9:00 AM - 6:30 PM

The BigBOSS instrument is a proposed fiber-fed spectrograph for the Mayall 4 m telescope at Kitt Peak, Arizona, which will measure the redshift of 20 million galaxies and map the expansion history of the universe over the past 8 billion years, surveying 10-20 times the volume of existing studies. The focal plate of the new telescope's prime focus optics will be populated with 5,000 robotic fiber positioners, each targeting and tracking an individual galaxy with every single exposure. The center-to-center pitch

between positioners is 12 mm. For complete areal coverage of the focal plane, positioners must patrol overlapping zones of at least diameter 14 mm. Strict light throughput requirements demand lateral and defocus errors of the positioners not to exceed ±15 μm, with a maximum tilt error of 0.15° at the fiber tip. In our poster, we present the design, and performance of a newly developed fiber positioner with R-θ kinematics, in which a flexure-based linear R-axis is stacked on a rotational θ-axis. Benefits over the established parallel axis θ-θ approach (e.g. Lamost, Cobra) include larger patrol area, simplified anti-collision schemes for repositioning, and reduced assembly tolerance chain. Results from sub-component hardware characterization are also presented, defining positioner specifications suitable to meet science requirements and technical feasibility.

335.12 – **The BigBOSS QSO Pilot Survey**

Adam D. Myers[1], N. Palanque-Delabrouille[2], D. J. Schlegel[3], C. Yeche[2], E. Aubourg[2], S. Bailey[3], A. Dey[4], S. Eftekharzadeh[1], X. Fan[5], C. Magneville[2], I. Paris[6], P. Petitjean[6], N. P. Ross[3]

[1]University of Wyoming, [2]CEA-Saclay, France, [3]Lawrence Berkeley National Lab, [4]NOAO, [5]University of Arizona, [6]Universite Paris, France.

9:00 AM - 6:30 PM

Future cosmological spectroscopic surveys of quasars will demand quasi-exhaustive target selection in both the “low-z” (redshifts of about 1.0 to 2.5) and the “mid-z” (redshifts of about 2.5 to 4.0) regimes. In combination, low-z and mid-z quasars can constrain the geometry of the Universe from the Baryon Acoustic Oscillation (BAO) feature in both quasar clustering and in the Lyman-alpha forest. But, target selection of quasars to the depths afforded by next-generation imaging surveys remains difficult, in particular because color-based selection of *mid-z* quasars−for which the optical colors of stars and quasars are similar−is highly inefficient. To help refine the selection of faint quasars for future surveys like BigBOSS, we have developed a method based on optical variability to target quasars up to g~23 and z~4, with a completeness better than 85%. Our method overcomes the drawbacks of color selection, which systematically misses quasars near $2.5 < z < 3.5$. We have conducted a pilot survey within SDSS III/BOSS covering 16 square degrees, complemented by a 4 square degree survey on the MMT to study the fainter targets. We aim to determine the number density of quasars that BigBOSS will be able to use to constrain dark energy.

ADM acknowledges support from the Alexander von Humboldt Foundation.

335.13 – **Emission Line Galaxies for BigBOSS**

Nick J. Mostek[1], K. Barbary[2], A. Dey[3], R. Kennedy[4], A. Kim[2], J. Kneib[5], J. Newman[6], P. Nugent[2], N. Padmanabhan[7], D. Schlegel[2], BigBOSS Collaboration

[1]UC Berkeley / Space Sciences Laboratory, [2]Lawrence Berkeley National Laboratory, [3]National Optical Astronomy Observatory, [4]UC Berkeley, [5]Laboratoire d'Astrophysique de Marseille, [6]University of Pittsburgh, [7]Yale University.

9:00 AM - 6:30 PM

We present a simple optical selection of star-forming emission line galaxies (ELGs) at intermediate redshifts appropriate for BigBOSS. These galaxies exhibit very blue restframe colors and are selected for their bright [OII] doublet emission, ideal for both fast and secure redshift measurements from the ground. The selection is based on (g-R) colors generated from co-added Palomar Transient Factory photometry in the COSMOS field. From the selected sample, we generate ~3000 galaxies per sq. deg. and show that the bulk of the detected redshifts expected from BigBOSS will range from $0.6<z<1.6$. We also detail the general properties of similarly-selected ELGs from DEEP2, including distributions of the [OII] emission line flux and stellar mass, and measure the clustering bias relative to dark matter halos as a function of redshift.

335.14 – **The Delivered Image Quality with the MOSAIC Cameras at the Kitt Peak 4m Mayall and Cerro Tololo 4m Blanco Telescopes**

Arjun Dey[1], F. Valdes[1]

[1]NOAO.

9:00 AM - 6:30 PM

We analyze several thousand archival images from the NOAO Science Archive obtained over the last five years using the KPNO 4m Mayall and CTIO 4m Blanco MOSAIC cameras in order to determine the delivered image quality. We fit the resulting point spread functions with Moffat functions and find that the profiles are well approximated with beta approximately 3.5. We then analyze the DIQ distributions and investigate their dependence on various observational, environmental and temporal variables. We find that the DIQ of the MOSAIC cameras is similar at both sites.

335.15 – **Spanish Participation In The Bigboss Project: Focal Plate And Fiber Positioner Design And Prototype**

Francisco Prada[1]

[1]Instituto De Astrofisica De Andalucia (CSIC), Spain.

9:00 AM - 6:30 PM

The BigBOSS Spanish Consortium is providing scientific and technical effort to the BigBOSS project for various work package tasks. The current research institutes that are members of the BigBOSS collaboration in Spain are the IAA-CSIC, IAC, ICC-UB, IFT UAM-CSIC and OA-UV. Participation by the Spanish Consortium is currently addressing one of the major technical risks in the BigBOSS project: the Focal Plane Assembly. We have been working since January 2010 on the requirements, concept and design of the focal plate and the fiber positioner robot for this new instrument. In this poster, we present the progress on our instrumentation development activities during the conceptual and preliminary design phase. We also report on the prototyping of our BigBOSS fiber positioner and the construction of a sub-scale focal plate prototype.

335.16 – **Spectroscopic Observation of Emission Line Galaxies at z~1 with the Sloan Telescope: Implications for Future Surveys**

Johan Comparat[1], J. Kneib[1], S. Escoffier[2], A. Ealet[2], J. zoubian[1], F. Lamareille[3], D. Schlegel[4], BOSS Collaboration, BigBOSS Collaboration

[1]LAM/CNRS, France, [2]CPPM/CNRS, France, [3]IRAP/CNRS, France, [4]LBNL Berkeley.

9:00 AM - 6:30 PM

We observed emission line galaxies (ELG) in the redshift range [0.6,1.6] with 2.5m Sloan telescope spectrograph.

We explored two different color selections using the SDSS or CFHT-LS photometry u, g, r, and g, r, i, in order to select ELGs in different redshift bins. For this survey, the typical 5 sigma flux detection limit of the [OII] emission line is 5e-17 erg/s/cm^2. We assembled a dataset of about one thousand spectra of ELGs. The highest redshift confirmed by the detection of the [OII] doublet is 1.622. In the case of a photometry as precise as CFHT-LS, up to 80% of the selected targets have a reliable redshift assigned.

These results combined with simulations confirm the feasibility of massive ELG surveys for a first BAO measurement in the redshift window 0.6-1.6 using BOSS spectrograph, giving the strongest support to BigBOSS observation strategy regarding ELGs.

335.17 – **Optical Fiber Systems for the BigBOSS Instrument**

Jerry Edelstein[1], J. R. Allington-Smith[2], R. W. Besuner[3], C. J. Bebeck[3], P. J. Jelinsky[1], R. E. Lafever[3], G. J. Murray[2], C. Poppett[3], M. J. Sholl[1], J. H. Silber[3], C. Schenk[3]

[1]University of California, [2]Durham University, United Kingdom, [3]Lawrence Berkeley National Lab..

9:00 AM - 6:30 PM

BigBOSS is a proposed instrument for the Mayall 4-meter telescope at Kitt Peak. Its prime objective is to explore dark energy using the baryon acoustic oscillation method by measuring tens of millions of galaxy redshifts. The instrument uses massively multi-object spectroscopy to measure this large number of objects with an optical system that includes 5000 optical fibers, each actuator-positioned at the prime-focus focal plane. The fibers will be routed from prime focus, through the telescope in ten, 40-meter long bundles to an optics bay. Each 500-fiber bundle terminates at a three-band spectrograph with the fibers arranged into a 12.5 cm convex slit and pointed to a common pupil to feed the spectrograph optics. In our poster, we describe the BigBOSS fiber system requirements and design.

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336 – Large Scale Structure, Cosmic Distance Scale

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

336.01 – **The 6dFGS Peculiar Velocity Field**

Chris M. Springob[1], C. Magoulas[2], M. Colless[1], J. Mould[3], P. Erdogdu[4], D. H. Jones[5], J. Lucey[6], L. Campbell[7], A. Merson[6], T. Jarrett[8]

[1]Australian Astronomical Observatory, Australia, [2]University of Melbourne, Australia, [3]Swinburne University of Technology, Australia, [4]University College London, United Kingdom, [5]Monash University, Australia, [6]University of Durham, United Kingdom, [7]University of Western Kentucky, [8]Spitzer Science Center, California Institute of Technology.

9:00 AM - 6:30 PM

The 6dF Galaxy Survey (6dFGS) is an all southern sky galaxy survey, including 125,000 redshifts and a Fundamental Plane (FP) subsample of 10,000 peculiar velocities, making it the largest peculiar velocity sample to date. We have fit the FP using a maximum likelihood fit to a tri-variate Gaussian. We subsequently compute a Bayesian probability distribution for every possible peculiar velocity for each of the 10,000 galaxies, derived

from the tri-variate Gaussian probability density distribution, accounting for our selection effects and measurement errors. We construct a predicted peculiar velocity field from the 2MASS redshift survey, and compare our observed 6dFGS velocity field to the predicted field. We discuss the resulting agreement between the observed and predicted fields, and the implications for measurements of the bias parameter and bulk flow.

336.02 – **Cosmic Voids As Standard Rulers For Cosmology**

Guilhem Lavaux[1], B. D. Wandelt[2]

[1]*University of Waterloo, Canada,* [2]*UPMC, Universite Paris 06 / Institut d'Astrophysique de Paris, France.*
9:00 AM - 6:30 PM

We show a purely geometrical method for probing the expansion history of the Universe from the observation of the shape of stacked voids in spectroscopic redshift surveys. This method is an Alcock-Pasczynski test based on the average sphericity of voids posited on the local isotropy of the Universe, which acts as rulers of unknown size. We describe the algorithm that we use to detect and stack voids in redshift shells on the light cone. We establish, and test on N-body simulation, a robust statistical model for estimating the average stretching of voids in redshift space. Finally, we discuss the constraining power on dark energy parameters in terms of the figure of merit of the Dark Energy Task Force. We estimate the figure of merit for SDSS, BOSS and EUCLID class surveys. For Euclid, the figure of merit is an order of magnitude higher than Baryonic Acoustic Oscillation based methods.

We acknowledge financial support from NSF Grant AST 07-08849, AST 09-08693 and from BDW's Chaire d'Excellence granted by the Agence Nationale de Recherche. GL acknowledges support from CITA National Fellowship and financial support from the Government of Canada Post-Doctoral Research Fellowship.

336.03 – **Characterizing Cosmic Voids in Large Scale Simulations**

Ali Sneddon[1], L. Phillips[1]

[1]*University of Notre Dame.*
9:00 AM - 6:30 PM

The scale of cosmic voids was first realized in the early 1980's with the advent of large galaxy redshift surveys. The voids and the galaxies they host can provide insight into the evolution of galaxies individually and the Universe as a whole. Analyzing these voids and their contents is, however, complicated by the difficulty of defining exactly what a void is. This was partially remedied by a recent comparison of thirteen different void finders on a region of the Millennium Simulation.

Here we present a computer vision algorithm that has been modified to identify and extract structures in large-scale simulations (clusters, filaments, voids). Comparing our results in the same region of the Millennium Simulation, we can identify and characterize the same large void region as the other algorithms do. We also catalog and characterize the void density, distribution, and evolution as calculated from the galaxy, dark matter, and baryonic distributions of a separate large scale hydrodynamical simulation

336.04 – **Power Spectrum Forecasts for Lyα Forest Baryon Acoustic Oscillation Experiments Using a GPU Based Semi-Analytical Model**

Bradley Greig[1], J. S. Bolton[1], J. S. B. Wyithe[1]

[1]*The University of Melbourne, Australia.*
9:00 AM - 6:30 PM

High redshift measurements of the baryonic acoustic oscillation scale (BAO) from large Lyα forest surveys represent the next frontier of dark energy studies. As part of this effort, efficient simulations of the BAO signature from the Lyα forest will be required. We present a calibrated semi-analytical method for producing very large simulations equivalent in size and resolution to the largest N-body simulations, but generated in less than a day on a single desktop PC. The efficiency of our simulations is obtained by utilising a single graphics processing unit (GPU). The Lyα forest spectra extracted from our simulations are in excellent agreement with both hydrodynamical simulations and are in broad agreement with observational measurements. We correctly extract the input BAO scale from the 3D Lyα forest power spectrum, and estimate that for a BOSS-like 10,000 square degree survey with ~15 background sources per square degree and a S/N of ~ 5 per pixel should achieve an accuracy of 1.4% on the measurement of the BAO scale. The speed and flexibility of our approach is well suited for exploring parameter space and the impact of observational and astrophysical systematics on the recovery of the BAO signature from forthcoming large scale spectroscopic surveys.

336.05 – **Nonlinear Redshift-Space Behavior of Baryon Acoustic Oscillations from the Zel'dovich Approximation**

Nuala McCullagh[1], A. S. Szalay[1]

[1]*Johns Hopkins University.*
9:00 AM - 6:30 PM

Baryon acoustic oscillations have become the favored technique to measure and constrain the properties of dark energy. An accurate model of the effects of both non-linearities and redshift-space distortions on the location and strength of the acoustic peak is necessary in order to characterize the equation of state of dark energy. Here, we consider non-linearities and redshift-space distortions using the Zel'dovich approximation and a novel approach to 2nd order perturbation theory. Linear theory predicts that the power spectrum grows as the square of the growth factor, D(t). However, higher-order terms may have a non-negligible contribution at later times, as the acoustic scale is in the mildly non-linear regime at low redshift. It is necessary to understand the effect of the coordinate transformation from real to redshift space on these higher-order terms. In the Zel'dovich approximation, the second-order term of the power spectrum is built from convolutions of the linear power spectrum with polynomial kernels in Fourier space. We show that in configuration space, this term can be written as a sum of second order products of a broader class of correlation functions, expressed through simple spherical Bessel transforms of the linear power spectrum. Next we demonstrate how this expression can be straightforwardly transformed to redshift space. Finally, we compare our expressions to numerical simulations.

336.06 – **Tomographic Weak Gravitational Lensing Magnification with the Deep Lens Survey**

Christopher Morrison[1], R. Scranton[1], S. Schmidt[1], J. Tyson[1], D. Wittman[1]

[1]*UC Davis.*
9:00 AM - 6:30 PM

Using half a million galaxies from the Deep Lens Survey, we have measured the gravitational lensing-induced magnification of high redshift ($z \sim 4$) Lyman Break Galaxies (LBGs) by foreground field galaxies at a S/N > 20, finding a signal consistent with the expected lensing behavior. Using photometric redshifts, we can further divide our foreground galaxies into 8 roughly equal sub-groups covering the redshift range $0.4 < z < 1.2$, which spans the expected lensing efficiency peak. After accounting for the evolution in large scale bias, we find that the measured lensing signal for the 8 sub-samples is consistent with the expected tomographic signal in LambdaCDM with a sigma8 given by WMAP CMB data. We find that these results are robust against systematic effects from variations in survey depth, seeing, and extinction as well as cross-contamination between the photometric redshift-selected foreground and LBG samples.

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337 – Young Stellar Objects, Very Young Stars, T-Tauri Stars, H-H Objects

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

337.01 – **Understanding The Evolution Of Sun-like Stars: IRAS 4**

Danna Qasim[1], J. McMullin[2], S. Myers[2], M. Goss[2], G. Sandell[3]

[1]*NRAO REU,* [2]*NRAO,* [3]*SOFIA.*
9:00 AM - 6:30 PM

We present high resolution EVLA observations of the dust and gas in the NGC 1333 IRAS 4 star forming region, focusing on the class 0 protostars, IRAS 4A1/4A2 and IRAS 4B. Dust properties are derived from the spectral energy distribution over the 6-10 millimeter regime, reviewing extrapolations to both longer and shorter wavelengths. Emission distributions and LTE column densities are derived at ~100 AU scales for a series of molecular tracers (SiO, SO2, OCS, CH3OH, CH3OCHO, CS and H2CO), highlighting evolutionary differences between the stars forming in close proximity, and for IRAS 4A, within a common natal envelope.

337.02 – **The Impact Of Molecular Outflows In The Protostellar Cluster NGC1333**

Adele Plunkett[1], H. G. Arce[1], S. A. Corder[2]

[1]*Yale University,* [2]*NRAO/ALMA.*
9:00 AM - 6:30 PM

The study of embedded protostellar clusters is critical to understanding the complex environments where stars are most likely to form. In these dense cluster environments, energetic outflows accompany star formation, injecting momentum and energy into the cloud and likely feeding turbulent motion. NGC1333 is the ``prototypical'' nearby region for studying clustered star formation, as well as for modeling outflow-driven turbulence. We present CARMA observations of CO in NGC1333, mapping the region teeming with multiple interacting molecular outflows. The angular and velocity resolutions of CARMA allow us to search for previously undetected outflow candidates. By combining interferometer and single dish maps, our observations are sensitive to structures on scales of 0.006 to 1 pc at a distance 250 pc, significant for understanding turbulence and its impact on size scales of cores to clusters. We have determined the mass, momentum, and energy imparted by molecular outflows on these scales, and we show the outflows' impacts on the cloud structure and dynamics.

337.03 – **A Chandra and Spitzer Study of IC 348**

Alex Spatzier[1], C. Espaillat[2], J. Forbrich[2], S. Wolk[2]

[1]*Oberlin College,* [2]*CfA.*
9:00 AM - 6:30 PM

We present a multi wavelength study of the young stellar cluster IC 348 making use of new Chandra X-ray observations as well as existing Spitzer infrared data. Overall, 484 X-ray sources were detected of which 271 correspond to known 2MASS or Spitzer IRAC cluster members. We find that classical T Tauri Stars and weak-lined T Tauri Stars show similar mean X-ray luminosities. Transitional disk X-ray luminosities are investigated and compared to transitional disks in other young clusters. We report the detection of 22 hard X-ray photons from the vicinity of HH211's NW jet and possible scenarios for their origin are discussed. This work is supported in part by the NSF REU and DOD ASSURE programs

under NSF grant no. 0754568 and by the Smithsonian Institution.

337.04 – **The Interstellar Bullet Engine IRAS05506+2414: A Molecular-Line Study**

Raghvendra Sahai[1], N. Patel[2], M. J. Claussen[3], C. Sanchez Contreras[4], M. R. Morris[5]

[1]*JPL,* [2]*CfA,* [3]*NRAO,* [4]*CSIC-INTA, Madrid, Spain,* [5]*UCLA.*
9:00 AM - 6:30 PM

High-mass stars play a decisive role in the evolution of galaxies. An exciting recent development in the understanding of those early evolutionary stages, based on a new study of the Orion BN/KL region, is that the disruption of a massive young stellar system can lead to an explosive event producing a wide-angle outflow. This is an entirely different phenomenon from the classical bipolar flows driven by YSO accretion disks. We report here preliminary results from a molecular-line study of a serendipitously discovered object, IRAS05506+2414, which most likely is only the second known example of this phenomenon in our Galaxy.

Our HST images show a fan-like spray of high-velocity (up to 350 km/s) elongated knots which appear to emanate from a bright compact central source. The physical properties (opening angle, outflow speeds, knot masses, Herbig-Haro-object like optical line emission) of the IRAS05506 wide-angle outflow are very similar to the one in Orion. A second jet engine, similar to those which drive the classical accretion-driven jets seen in low-mass YSOs, also appears to be operating simultaneously in IRAS05506. This is indicated by an optical jet-like feature aligned with a high-velocity (>100 km/s) molecular outflow which appears to be bipolar and nearly perpendicular to the average direction of the knot spray. Our molecular-line study includes (a) single-dish observations at 1.1-1.3 and 2.6-3 mm of high-density tracers such as HCO+, CS and SO, and mapping of the ambient molecular cloud in CO and 13CO using the ARO's 10- and 12-m dishes, and (b) interferometric observations at 2.6 and 1.3 mm with OVRO and the SMA of CO, 13CO, SO and SiO lines and the dust continuum. Preliminary results on the mass, density and temperature of the outflow and ambient cloud using simple excitation/radiative transfer models will be presented.

337.05 – **Spitzer-Selected Young Stellar Objects in Two Bright Rimmed Clouds**

Chelen H. Johnson[1], L. M. Rebull[2], J. C. Gibbs[3], M. Linahan[4], D. C. Sartore[5], M. Legassie[6], R. Laher[2], N. G. Killingstad[1], T. S. McCanna[1], A. M. O'Bryan[1], S. D. Carlson[1], M. L. Clark[1], S. M. Koop[1], T. A. Ravelomanantsoa[1], T. R. Nuthmann[3], T. S. Canakapalli[3], S. Aryal[3], M. M. Nishida[3], A. Ramswaram[4], H. N. Sprow[4], A. Pullinger[4], N. J. Ezyk[4], J. R. Fagan[4], C. M. Tilley[5], K. S. Badura[5]

[1]*Breck School (Minneapolis, MN),* [2]*Spitzer Science Center/Caltech (Pasadena, CA),* [3]*Glencoe High School (Hillsboro, OR),* [4]*Carmel Catholic High School (Mundelein, IL),* [5]*Pine Ridge High School (Deltona, FL),* [6]*Spitzer Science Center/Caltech and Raytheon (Pasadena, CA).*
9:00 AM - 6:30 PM

Found near the edges of HII regions, bright-rimmed clouds (BRCs) are thought to be home to triggered star formation. Using Spitzer Space Telescope archival data, we investigated two BRCs, BRC 27 and BRC 34, to search for previously known and new candidate additional young stellar objects (YSOs). BRC 27 is located in the molecular cloud Canis Majoris R1, a known site of star formation. BRC 34 has a variety of features worthy of deeper examination: dark nebulae, molecular clouds, emission stars, and IR sources. Our team used archival Spitzer InfraRed Array Camera (IRAC) and Multiband Imaging Photometer for Spitzer (MIPS), combined with 2-Micron All-Sky Survey (2MASS) data. We investigated the infrared properties of previously known YSOs and used infrared colors to identify additional new candidate YSOs in these regions. This research was made possible through the NASA/IPAC Teacher Archive Research Project (NITARP) and was funded by NASA Astrophysics Data Program and Archive Outreach funds.

337.06 – **Discovery of ~15 Myr Old pre-Main Sequence Stars with Active Accretion and Sizeable Discs in NGC 6611**

Guido De Marchi[1], N. Panagia[2], M. G. Guarcello[3], R. Bonito[4]

[1]*ESA, Netherlands,* [2]*STScI,* [3]*CfA,* [4]*INAF-PA, Italy.*
9:00 AM - 6:30 PM

Attention is given to a population of 110 stars with prominent near-infrared (NIR) excess in the NGC 6611 cluster of the Eagle Nebula that have optical colours typical of pre-main sequence (PMS) stars older than 10 Myr. In principle, their V-I colours would be consistent with those of young PMS objects (< 1 Myr), whose radiation is heavily obscured by a circumstellar disc seen at high inclination and in small part scattered towards the observer by the back side of the disc. However, using theoretical models it is shown here that objects of this type can only account for a few percent of this population. In fact, the spatial distribution of these objects, their X-ray luminosities, their optical brightness and their positions in the colour-magnitude diagram unambiguously indicate that most of these stars are intrinsically older than 10 Myr. Ages range from ~8 to ~30 Myr with a median value of 15 Myr. This is the largest homogeneous sample to date of Galactic PMS stars considerably older than 10 Myr that are still actively accreting from a circumstellar disc and it allows us to set a lower limit of 5% to the disc frequency at 15 Myr in NGC 6611. These values imply a characteristic exponential lifetime of ~5 Myr for disc dissipation.

337.07 – **Young Stellar Variability in the North America Nebula**

Krzysztof Findeisen[1], L. Hillenbrand[1]

[1]*Caltech.*
9:00 AM - 6:30 PM

Although variability is a common property of newly formed stars, so far the full breadth of periodic and aperiodic variability in young stars has not been studied in quantitative detail. We are using the Palomar Transient Factory (PTF) to carry out a multi-season survey of the North America Nebula complex. In addition to improving the membership list for this poorly-studied star forming region, our survey will provide a systematic look at both periodic and aperiodic variability in young stars. Aperiodic variables are a relatively unexplored area of young star research compared to periodic variables, whose easily quantifiable periods make them relatively simple to analyze. By addressing both kinds of variability we will obtain a clearer picture of the diverse processes that affect stars in their early evolution. We present preliminary work toward characterizing the variables in our sample.

337.08 – **Echelle Spectra of Candidate Young Stellar Objects in the Serpens Main Cluster**

Kristen Erickson[1], B. Wilking[1], J. Kim[2], M. Meyer[3]

[1]*UMSL,* [2]*Steward Observatory,* [3]*Institute for Astronomy Swiss Federal Institute of Technology, Switzerland.*
9:00 AM - 6:30 PM

We have obtained high-resolution (R = 33000) echelle spectra for 18 stars in the direction of the Serpens Main Cluster using the double Magellan Inamori Kyocera Echelle (MIKE) spectrograph on the Clay 6.5m telescope. These objects have been previously observed as part of a comprehensive, mid-resolution optical spectroscopic survey of candidate young stellar objects (YSOs) in Serpens Main. Eleven of the echelle targets are known YSOs, including 2 transition disk objects. The remaining objects are unclassified sources. Signatures of youth and surface gravity will verify the nature of these objects. Accretion rates will be estimated from the hydrogen, He I, O I, and Ca II IR triplet emission lines. These spectra will also be used to determine radial velocities and infer the average velocity and velocity dispersion of the cluster. These data are part of a larger project to investigate the star forming history, initial mass function and disk evolution for YSOs in the Serpens molecular cloud.

337.09 – **Testing Magnetospheric Accretion Theories in NGC 2264**

Paul Wilson Cauley[1]

[1]*Rice University.*
9:00 AM - 6:30 PM

Classical T Tauri stars (CTTSs) are young stars still surrounded by circumstellar accretion disks. The currently accepted theory for how matter is accreted onto the central star from the disk is *magnetospheric accretion*: stellar magnetic fields truncate the disk at 3R*-6R* and channel material from the disk onto the surface of the star at near free-fall velocities. The infalling material heats up as it impacts the stellar photosphere and emits strongly at optical and UV wavelengths, creating excess emission that can veil the underlying stellar spectrum. We determine mass accretion rates for 35 stars in the ~ 3 Myr old open cluster NGC 2264 and test specific relationships between the stellar and accretion parameters as predicted by the current magnetospheric accretion theory. To find accretion rates, we model the excess accretion emission using an isothermal, pure hydrogen slab in LTE. The observed spectrum is then fit by a combination of the slab emission and a non--accreting stellar template, each of which is subject to a model-dependent reddening value. The final fits provide estimates of the stellar mass, radius, filling factor of the accretion column on the stellar surface, and mass accretion rates. Our observations are well fit by this simple treatment of the excess emission. Using the stellar parameters and accretion rates from the fits, we find an excellent correlation (r=.90) for the relationship predicted by a modified version of the Shu et al. (1994) magnetospheric accretion theory. The modified theory relaxes the stellar dipole magnetic field requirement in favor of a random surface geometry. Our

results support the conclusion that magnetospheric accretion governs the mass accretion in CTTSs. Comparisons with accretion rates derived from U-band photometry are also presented. This work is supported by NASA Origins of Solar Systems grant NNX08AH86G.

337.10 – **Did All the Stars in Upper Scorpius Form in a Single Burst?**

Alycia J. Weinberger[1], G. Anglada-Escude[1], A. P. Boss[1]

[1]*Carnegie Inst. Of Washington.*

9:00 AM - 6:30 PM

We are measuring parallactic distances to low mass (mainly M0-M5 spectral type) stars in Upper Scorpius. We estimate better the ages of individual disk-bearing stars and assess the age spread within the association. Pecaut et al. (2011) have recently reassessed the average age of Upper Sco at 10 Myr. However, even a spread of a couple million years in this average age affects our understanding of circumstellar disk lifetimes, because it appears disks dissipate with a timescale of ~3 Myr. The Upper Scorpius OB association, which is 140 pc away, covers ~300 square degrees. *Hipparcos* parallax uncertainties on the O-G type stars were too large to measure the depth of the association, but de Bruijne (1999) estimated it at 50-60 pc. Yet the stars over this large volume appear to be approximately coeval. We have assembled a sample of 20 each of disk and disk-less stars from Carpenter et al. (2006). We are using the Carnegie Astrometric Planet Search Camera to measure parallaxes with precisions of ~1 mas. For these stars with well known luminosities, we will compare the ages of the two groups. We will also assess the average age of the low mass stars compared to the higher mass stars studied with *Hipparcos*. Here, we will report on the first 13 stars, six with disks and seven without.

337.11 – **WFC3 Imaging of Protostars in the Orion Molecular Clouds**

Marina Kounkel[1], T. Megeath[1], W. Fischer[1], C. Poteet[1]

[1]*Univ. Of Toledo.*

9:00 AM - 6:30 PM

The Orion molecular clouds contain the largest sample of protostars within 500 pc of the Sun. We present results from HST/WFC3 imaging of 124 fields in Orion containing previously identified protostars. Combined with imaging from the HST/NICMOS camera, these data provide high resolution 1.6 micron images of 260 protostars. These data are being combined with Spitzer and Herschel imaging and spectra to construct complete spectral energy distributions from 1.6 to 160 microns for the entire sample of protostars. We present a search for companions to the protostars using the WFC3/NICMOS imaging, which has the capability to identify objects at separations as small as 100 AU. We present here the mean surface density of sources as a function of distance from the protostars and use this to identify candidate companions. The 1.6 micron photometry is combined with 3.6 micron data from Spitzer and the IRTF to measure the colors of the candidate companions and determine whether they are protostars. We demonstrate that the longer wavelength observations are essential for identifying the most deeply embedded companions. We also discuss the incidence of scattered light nebulae surrounding the protostars, as detected in the WFC3/NICMOS images. These nebulae, which often show a bipolar morphology, are created by light scattered from the infalling envelope.

337.12 – **Infrared and Submillimeter Observations Of IRAS 03245+3002**

Kirstin D. Doney[1], H. Kim[1], N. J. Evans[1]

[1]*University of Texas at Austin.*

9:00 AM - 6:30 PM

We present a study of a young stellar object in the embedded phase, IRAS 03245+3002, which is part of the Dust, Ice, and Gas In Time (DIGIT) project which is designed to span the full range Lbol-Tbol diagram. The *Spitzer Space Telescope* and ground-based telescopes, 2MASS and CSO, have observed the object in the infrared and submillimeter wavelengths. The photometric data give constraints on the radiative transfer modeling and give an bolometric luminosity of $4.6L_{\odot}$. We also present the molecular line observations of six species toward IRAS 03245+3002 taken at CSO, the molecular line modeling, of which are still on going, will give an expectation of the molecular abundances of the source and will be presented in the poster.

I would like to acknowledge Dr. Neal J. Evans II, Hyo Jeong Kim, and the University of Texas at Austin for their help and support.

337.13 – **Simulations of Protoplanetary Disk Turbulence: Connecting Theory and Observations**

Jacob B. Simon[1], P. J. Armitage[2], K. Beckwith[1]

[1]*JILA, University of Colorado,* [2]*JILA and Department of Astrophysical and Planetary Sciences, University of Colorado.*

9:00 AM - 6:30 PM

For comparison with recent measurements of turbulent line broadening in protoplanetary disks, we present a series of local magnetohydrodynamic (MHD) simulations of the magnetorotational instability (MRI) in protoplanetary disks. We use these simulations to characterize the distribution of turbulent velocities in such disks, as a function of radius and height above the mid-plane. These simulations include ideal MHD calculations as well as calculations with an MRI-inactive dead zone created by a height-dependent Ohmic resistivity. In the ideal case, the disk mid-plane is characterized by a velocity distribution that peaks near 0.1 of the local sound speed, while supersonic velocities are reached at $z > 3H$ (where H is the vertical pressure scale height). Velocities of 0.01 of the sound speed persist near the mid-plane in dead zones, but the MRI-active surface layers have velocities characteristic of the ideal MHD runs (including a supersonic component). The velocities in the surface layers are roughly consistent with recent sub-mm observations. We also compare our MHD results to hydrodynamic simulations in which large-scale forcing is used to initiate similar turbulent velocities. The qualitative trend of increasing velocity with height, seen in the MHD case, persists for forced turbulence and is likely a generic property of disk turbulence. These velocity distributions are highly isotropic, suggesting that the disk inclination angle plays a very minor role. Based on these results, very precise measurements of the turbulent velocity at different heights within the disk or spatially resolved observations that probe the inner disk and the dead zone region are needed to test whether the MRI is responsible for protoplanetary disk turbulence. We acknowledge support from both NASA and NSF in carrying out this work.

337.14 – **RX J0513.1+0851 and RX J0539.9+0956: Two Young, Rapidly Rotating Spectroscopic Binary Stars**

Dary Ruiz[1], L. Prato[1], L. H. Wasserman[1], G. Torres[2], R. Neuhauser[3]

[1]*Lowell Observatory,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*Astrophysikalisches Institut, Universitat Jena, Germany.*

9:00 AM - 6:30 PM

Pre-main sequence spectrsocopic binaries provide an invaluable tool for determinations of dynamical mass ratios and, ultimately, absolute masses. RX J0513.1+0851 and RX J0539.9+0956 were initially identified as young, low-mass, single-lined spectroscopic binary systems and classified as weak-lined T Tauri stars. These systems have high rotational velocities of 50 km/s and 80 km/s, respectively. We used near-infrared spectroscopy taken with NIRSPEC on Keck II to provide a first detection of these systems as double-lined rather than single-lined. The low-mass secondary component is cooler and redder than the primary component. The flux scales as a less steep function of mass in the infrared than in the visible, thus we are more sensitive to detection of lower-mass secondary stars in the infrared. We measured the radial velocities and estimated the spectral types, vsini values, and flux ratios using two-dimensional cross-correlation. The orbital parameters and mass ratios were calculated by combining existing visible light data and our new infrared data for both systems. Results from our initial analysis indicate that RX J0513.1+0851 may be a member of an older population. We derive periods of ~4 days and ~1130 days for RX J0513.1+0851 and RX J0539.9+0956, respectively.

337.15 – **Chandra Reveals Unusual X-ray Emission from the Jet-Driving T Tauri Star RY Tau**

Steve L. Skinner[1], M. Audard[2], M. Guedel[3]

[1]*Univ. of Colorado,* [2]*ISDC, Univ. of Geneva, Switzerland,* [3]*Univ. of Vienna, Austria.*

9:00 AM - 6:30 PM

We report results of a sensitive 56 ksec Chandra ACIS-S observation of the classical T Tauri star RY Tau. Chandra reveals complex X-ray emission that includes a very soft non-variable spectral component (some of which likely originates in shocks), a variable superhot flaring component ($T > 100$ MK) that is undoubtedly of magnetic origin, and faint soft X-ray emission extending outward to the northwest overlapping the forward (blueshifted) axis of the known optical jet. We summarize the X-ray spectral and timing behavior of RY Tau and discuss possible explanations of the faint extended emission in the context of X-ray jet models and a possible close companion.

This research was supported by Chandra award GO0-11028X issued by the Chandra X-ray Observatory Center.

337.16 – **A Spectro-Astrometric Measurement of Brackett Gamma Emission in Herbig Ae/Be Stars**

Thomas Rice[1], S. Brittain[2]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Clemson University.*

9:00 AM - 6:30 PM

In T Tauri stars, the Brackett-gamma line strength is a reliable indicator of accretion luminosity. Among intermediate mass young stars, Herbig Ae stars also show this correlation, but in Herbig Be stars the Br-gamma line flux significantly overpredicts accretion luminosity. This Br-gamma excess in Herbig Be stars is thought to arise from a spatially extended outflow. Using commissioning data from the LUCIFER spectrograph on the 8.4-meter Large Binocular Telescope (LBT), we present a spectro-astrometric study of two Herbig Ae/Be stars, the HAe star MWC480 and the HBe star HD 259431. In both stars, an extended Br-gamma source can be ruled out down to 0.001" at the 1σ level. We discuss the implication of our limits on the extension of the Br-gamma emission and possible ways forward.

338 – Galaxy Clusters

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

338.01 – **Far-infrared Survey of Brightest Cluster Galaxies with the Herschel Space Observatory**

Tim Rawle[1], E. Egami[1], M. Rex[1], A. Edge[2], Herschel Lensing Survey, LoCuSS

[1]*University of Arizona,* [2]*Durham University, United Kingdom.*

9:00 AM - 6:30 PM

We present far-infrared (FIR) analysis of 70 Brightest Cluster Galaxies (BCGs) at 0.08 < z < 1.0. Deriving total infrared luminosity (L_{IR}) directly from Spitzer/Herschel photometry spanning the peak of the dust component (24-500 μm), we calculate the obscured star formation rate (SFR_{FIR}). 15/70 (22%) of the BCGs are detected in the FIR, with SFR_{FIR} = 1-150 M_{sun}/yr. SFR_{FIR} is highly correlated with both the cluster X-ray cooling time and the occurrence of the cold gas tracing Halpha emission in the BCG. Only a modest reddening correction is required to account for Ha obscuration (<0.3 mag) in all but the most luminous ($L_{IR} > 2\times10^{11}$ L_{sun}) BCGs. The LIRG-type BCGs require ~1 mag of reddening and/or a correction for AGN contribution in the mid-infrared. We suggest that the link between BCG FIR and cluster cooling time is strong circumstantial evidence that SF is influenced, and plausibly fueled, by cluster-scale gas cooling. The dust properties of IR-bright BCGs are substantially similar to the general galaxy population, despite the different origin of the cold gas.

338.02 – **Diffusive Shock Acceleration Modeling of Radio Relics in Clusters of Galaxies**

Hyesung Kang[1], D. Ryu[2], T. W. Jones[3]

[1]*Pusan National Univ., Korea, Republic of,* [2]*Chungnam National Univ., Korea, Republic of,* [3]*Univ. of Minnesota.*

9:00 AM - 6:30 PM

Cosmological shock waves result from supersonic flow motions induced by hierarchical clustering during the large-scale structure formation in the Universe. Suprathermal particles are known to be produced via plasma interactions at collisionless shocks in tenuous plasmas and they can be further accelerated to become cosmic rays (CRs) via diffusive shock acceleration (DSA). The presence of CR electrons has been inferred from observations of diffuse radio halos and relics in some merging galaxy clusters. We have calculated the emissions from CR electrons accelerated at weak planar shocks, using time-dependent DSA simulations that include energy losses via synchrotron emission and Inverse Compton scattering. The simulated nonthermal emission are used to model the synchrotron emission from several observed radio relics. HK was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011-0002433).

338.03 – **A Simulation Study of Intracluster Turbulence**

Dongsu Ryu[1], D. H. Porter[2], T. W. Jones[2], J. Cho[1]

[1]*Chungnam National Univ., Korea, Republic of,* [2]*University of Minnesota.*

9:00 AM - 6:30 PM

Clusters of galaxies are the largest virialized structures in the universe, which serve as laboratories for the study of astrophysical processes on very large scales. Observations and theoretical arguments suggest that intracluster media is turbulent. The media are very hot and dynamic, highly rarefied, and probably magnetized at some level. The physics involved is complex and high-resolution simulations help us understand the physics and consequent phenomena. We are engaged in a simulation study designed to understand in this context how subsonic turbulence with very weak initial magnetic fields develops and evolves with imposed forcing. We find that the resulting turbulence is sensitive to the nature of forcing as well as the dissipation properties of the media.

The work was supported by the National Research Foundation of Korea through grant 2007-0093860.

338.04 – **Constraining the Evolution of Poor Clusters**

Emma J. Broming[1], C. R. Fuse[1]

[1]*Rollins College.*

9:00 AM - 6:30 PM

There currently exists no method by which to quantify the evolutionary state of poor clusters (PCs). Research by Broming & Fuse (2010) demonstrated that the evolution of Hickson compact groups (HCGs) are constrained by the correlation between the X-ray luminosities of point sources and diffuse gas. The current investigation adopts an analogous approach to understanding PCs.

Plionis et al. (2009) proposed a theory to define the evolution of poor clusters. The theory asserts that cannibalism of galaxies causes a cluster to become more spherical, develop increased velocity dispersion and increased X-ray temperature and gas luminosity.

Data used to quantify the evolution of the poor clusters were compiled across multiple wavelengths. The sample includes 162 objects from the WBL catalogue (White et al. 1999), 30 poor clusters in the Chandra X-ray Observatory archive, and 15 Abell poor clusters observed with BAX (Sadat et al. 2004).

Preliminary results indicate that the cluster velocity dispersion and X-ray gas and point source luminosities can be used to highlight a weak correlation. An evolutionary trend was observed for multiple correlations detailed herein.

The current study is a continuation of the work by Broming & Fuse examining point sources and their properties to determine the evolutionary stage of compact groups, poor clusters, and their proposed remnants, isolated ellipticals and fossil groups. Preliminary data suggests that compact groups and their high-mass counterpart, poor clusters, evolve along tracks identified in the X-ray gas - X-ray point source relation. While compact groups likely evolve into isolated elliptical galaxies, fossil groups display properties that suggest they are the remains of fully coalesced poor clusters.

338.05 – **Are Low-Mass Galaxy Clusters Overconcentrated?**

Matthew P. Wiesner[1], H. Lin[2], S. Allam[2], J. Annis[2], E. Buckley-Geer[2], H. Diehl[2], D. Kubik[2], J. Kubo[2], D. Tucker[2]

[1]*Northern Illinois University,* [2]*Fermi National Accelerator Laboratory.*

9:00 AM - 6:30 PM

The Sloan Bright Arcs Survey (SBAS) at Fermilab has discovered and confirmed 19 strong-lensing systems in the Sloan Digital Sky Survey. We used the WIYN telescope to take follow-up data on 10 of these systems, studying both the properties of the galaxy clusters and the properties of the strong gravitational lenses. We have found that the majority of our systems are lower-mass clusters, those with mass $\leq 10^{14}$ M$\odot$. Using this data we have found evidence to support other groups' findings of an overconcentration problem among galaxy clusters, the idea that galaxy clusters are more concentrated than ΛCDM would predict. It has recently been suggested that the overconcentration problem is most significant among low-mass clusters. We present our results for the relation between Einstein radius of the strong lenses and cluster mass (M_{200}). We show that the Einstein radii of the clusters are typically larger than would be expected based on current models, indicating that the clusters are overconcentrated.

338.06 – **A NEWFIRM Medium-Band Search for High Redshift Galaxy Clusters**

Adam R. Tomczak[1], K. H. Tran[1], C. J. Papovich[1], S. L. Finkelstein[2], G. H. Rudnick[3], C. N. A. Willmer[4]

[1]*Texas A&M University,* [2]*University of Texas,* [3]*University of Kansas,* [4]*University of Arizona.*

9:00 AM - 6:30 PM

We have obtained deep near-infrared imaging in the well-studied XMM-LSS field using the NEWFIRM instrument at CTIO to identify high redshift (z > 1.3) galaxy clusters. Our NEWFIRM pointing targets a single 30' x 30' field within the XMM-LSS where we have identified multiple candidate clusters as overdensities of sources with red Spitzer/IRAC colors from Papovich (2008). Our NEWFIRM imaging includes three medium-band (J1, J2, J3) and two broad-band (H, Ks) filters, and is 80% complete at 21.3 AB in Ks. Combined with existing CFHTLS optical imaging (ugriz), we achieve photometric redshifts accurate to a few percent, as these bands track the 4000 Angstrom/Balmer break through redshifts 1.3 < z < 2.0. Currently, our analysis of these data show three likely associations of galaxies from 1.3 < z < 2.0. We present properties of these three galaxy overdensities, including color-magnitude and color-radius relations, which support the idea that they are progenitors of present-day massive galaxy clusters.

338.07 – **Searching for Galaxy Clusters Around AGN at z~1 Using Spitzer Archival Imaging Data**

Shefali Mehta[1], M. Butler[2], A. Keeton[3], T. Spuck[4], M. Butler[5], C. Cook[1], M. Heller[6], P. Hutchinson[1], P. Hutchinson[1], W. Sixel[3], M. Abajian[7], A. Galametz[8], V. Gorjian[9]

[1]*Haddam-Killingworth High School, CT,* [2]*Orange County Astronomers, CA,* [3]*North High School, WI,* [4]*Oil City High School, PA,* [5]*Tuscarora High School, VA,* [6]*Clarion University of Pennsylvania,* [7]*Infrared Processing & Analysis Center/California Institute of Technology,* [8]*INAF - Osservatorio Astronomico di Roma, Italy,* [9]*JPL/Caltech.*

9:00 AM - 6:30 PM

We are using Spitzer Space Telescope archival data from the Infrared Array Camera (IRAC) at 3.6 and 4.5 microns to locate galaxy clusters at z~1. 168 fields that targeted Active Galactic Nuclei (AGN) at z~1 were taken from the archive and a [3.6] - [4.5] color selection was applied to all sources in each field. At a z~1 the peak of a galaxy's stellar emission is redshifted into the 3.6 micron band and so makes those galaxies bluer than foreground galaxies. If an overdensity of sources with the appropriate color was detected around the AGN, then the field was marked as having a potential cluster

around the AGN and will be followed up for spectroscopic confirmation.

338.08 – **High-performance GPU Models of Triaxial Galaxy Clusters**

Tyler Chapman[1], J. Smith[1]

[1]*SFSU.*

9:00 AM - 6:30 PM

We describe a code that harnesses the power of massively parallel GPU (graphical processing unit) computers to generate spatially resolved spectra of triaxial galaxy clusters. Using a self-consistent approach, and given a triaxial dark matter distribution in equilibrium with a hot plasma halo, the code solves the hydrostatic equilibrium equation. The resulting temperature profile is inserted into the emissivity function, and the spectra are co-added on a pixel-by-pixel basis to generate model spectra suitable for any X-ray mission. Each pixel on the detector runs as a separate thread on the GPU, and thousands of simultaneous threads are run to interpolate the cooling function and generate 3D spectra that are then co-added onto a 2D plane. The target architecture---Fermi Tesla Nvidia GPU---results in speed improvements of a factor between 10 and 100 over a typical clustered CPU-only setup.

338.09 – **Magnetic Fields, Faraday Rotation Measurement, And Radio Emissions Of Galaxy Clusters**

Hao Xu[1], H. Li[1]

[1]*Los Alamos National Lab.*

9:00 AM - 6:30 PM

We perform adaptive mesh refinement (AMR) cosmological magneto-hydrodynamic (MHD) simulations to investigate the evolution and distribution of magnetic fields in the intra-cluster medium (ICM) of galaxy clusters. We show that the cluster magnetic fields can be amplified and maintained by the ICM turbulence to the observed level at micro Gauss. The ICM MHD turbulence is excited and sustained by the frequent mergers during the cluster formation. This turbulence operates the small-scale dynamo process that transports and amplifies the fields. This process could be the primary process of populating the whole cluster with magnetic fields. The distribution of the magnetic fields are determined by the ICM turbulence and are not sensitive to the initial magnetic fields. We will show synthetic radio observations, e.g. Faraday rotation measurement and radio halos/relics, from our simulated clusters and then compare them with observations from VLA. The results show that the magnetic fields from our simulations are consistent with observations.

This work is supported by the LDRD and IGPP programs at LANL and by DOE/Office of Fusion Energy Science.

338.10 – **Chandra and XMM-Newton Observations of the Matter Profile in Nearby Clusters of Galaxies**

Weihan Chang[1]

[1]*San Francisco State University.*

9:00 AM - 6:30 PM

We conduct a joint analysis of observation from the Chandra and XMM-Newton X-ray telescopes of ~30 relaxed clusters. The spectra are extracted and fit with a spherical gas distribution in equilibrium with a generalized NFW profile. Key fit parameters include the total mass and the logarithmic slope and and concentration of dark matter profile in the cluster. Separate fits to the plasma thermodynamic properties without assuming hydrostatic equilibrium are also made. We present results on the mass-concentration, mass-slope, and concentration-slope relationship for the sample.

338.11 – **Hubble Observations Of A Spectacular Gravitationally Lensed Galaxy**

Jane R. Rigby[1], K. Sharon[2], M. D. Gladders[3], E. Wuyts[3], B. Koester[4], M. Bayliss[5], F. Barrientos[6]

[1]*NASA Goddard,* [2]*Kavli Institute for Cosmological Physics,* [3]*University of Chicago,* [4]*University of Michigan,* [5]*Harvard/Smithsonian Center for Astrophysics,* [6]*Pontificia Universidad Catlica de Chile.*

9:00 AM - 6:30 PM

We present dramatic new HST/WFC3 images of a bright lensed galaxy at z=1.7 that is magnified and stretched by the lensing cluster RCS2 032727-132623. From imagery in six broad-band filters (from F390W to F160W), we create a lens model, improving on our previous model from ground-based images (Wuyts et al. 2010). With this new lens model, we reconstruct the lensed galaxy in the source plane. The giant arc is magnified by 28x, though some regions of the galaxy are magnified by >200x. The high spatial resolution of the source plane images reveal a great deal of morphological complexity in this star-forming galaxy at z=1.7.

338.12 – **Galaxy Cluster Assembly: Cluster and Protocluster Populations**

Joel C. Berrier[1], J. S. Bullock[2], K. R. Stewart[3], D. Kennefick[1], J. D. Kennefick[1], M. S. Seigar[4], C. Lacy[1]

[1]*Department of Physics, University of Arkansas, Fayetteville, AR 72701,* [2]*Department of Physics and Astronomy, University of California Irvine, Irvine Ca 92697,* [3]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109,* [4]*Department of Physics and Astronomy, University of Arkansas Little Rock, Little Rock, AR 72204.*

9:00 AM - 6:30 PM

We study the formation of galaxy cluster-size dark matter halos ($M > 10^{14.0}$ M_{sun}) formed within a set of cosmological Lambda CDM N-body simulations, and track the accretion histories of cluster subhalos. We use the merger trees of these halos to trace their assembly and examine the populations of clusters/protoclusters in several different redshift intervals. Galaxy clusters provide an interesting environment for the study of several astrophysical phenomena, such as ram pressure stripping. They are the largest collapsing objects in the universe, and, as such, they are an observable constraint of hierarchical structure formation. Through understanding the formation of clusters, we probe key parameters in cosmology and such studies allow us to place constraints on several processes in the formation and evolution of galaxies as well as large scale structure.

338.13 – **Characterizing Galaxy Cluster Temperature Distributions**

Kari A. Frank[1], J. R. Peterson[1], K. Andersson[2], A. C. Fabian[3], J. S. Sanders[3]

[1]*Purdue Univ.,* [2]*MPE, Germany,* [3]*Univ. of Cambridge, United Kingdom.*

9:00 AM - 6:30 PM

Galaxy clusters are important tools for cosmology, particularly via their X-ray properties. Additionally, much of the physics of galaxy clusters is complex and not yet well understood. Both are complicated by a wealth of temperature substructure in the ICM, including shocks, X-ray cavities, cooling flows, and cold fronts. We aim to characterize both the shape and width of galaxy cluster temperature distributions, and search for correlations with other cluster properties, including median cluster temperature, luminosity, and size. 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 redshift, size, and emission measure. This allows us to measure the width of the temperature distribution, median temperature, total emission measure, and a characteristic cluster radius, as well as to characterize the shape of the temperature distribution. We apply this method to XMM-Newton observations of the HIFLUGCS galaxy cluster sample. We find that the temperature distribution is approximately log normal. Of 53 clusters, 19 have a temperature width consistent with isothermality, the remaining 34 clusters have a temperature width equal to approximately one-fourth of their median temperature.

338.14 – **Studies of ACT-CL J0102−4915 ("El Gordo") the Most Massive Known Galaxy Cluster at High Redshift**

John Patrick Hughes[1], F. Menanteau[1], ACT Collaboration

[1]*Rutgers Univ..*

9:00 AM - 6:30 PM

ACT-CL J0102−4915 is a massive galaxy cluster that was recently discovered by the Atacama Cosmology Telescope (ACT) based on the strength of its Sunyaev-Zeldovich effect signal. Follow-up observations with VLT/FORS2 and Chandra have provided precise values for the redshift (z=0.870), velocity dispersion (sigma = 1321±106 km/s), and integrated gas temperature (T_X = 14.5±0.1 keV). From several empirical scaling relations we estimate a total mass of M_{200}= (2.16±0.32)× 10^{15} M⊙, greater than all other known clusters at z>0.6, hence we dub ACT-CL J0102−4915 "El Gordo" (meaning The Big or Fat One in Spanish). Several lines of evidence from the optical and X-ray data strongly indicate that El Gordo is undergoing a major merger between components with a mass ratio of approximately 2 to 1. The cluster's X-ray morphology is complex with significant temperature variations from a low of 6.6±0.7 keV at the offset peak (the merging low-entropy, high-metallicity, cool core) to a high of 22±6 keV in an annulus approximately 1' from the centroid of the cluster. There is radio emission from the Sydney University Molonglo Sky Survey (SUMSS) at 843 MHz associated with the leading edge of the merging cool core as well as on the opposite edge of the cluster suggesting the possible presence of intense giant radio relics in El Gordo.

We gratefully acknowledge support from the NSF (PIRE-0507768 award number OISE-0530095) and NASA (Chandra grant number GO1-12008X).

338.15 – **The Local Cluster Survey: Probing Gas Depletion in Nearby Galaxy Groups and Clusters**

Rose Finn[1], A. Earle[1], A. McCann[1], G. Rudnick[2], V. Desai[3], R. Koopmann[4], K. Rines[5], M. Balogh[6], B. Poggianti[7], D. Zaritsky[8], M. Haynes[9], P. Jablonka[10], P. Jablonka[10]

[1]*Siena College,* [2]*U. Kansas,* [3]*IPAC,* [4]*Union College,* [5]*Western Washington University,* [6]*U. Waterloo, Canada,* [7]*U. Padova, Italy,* [8]*U. Arizona,* [9]*Cornell University,* [10]*EPFL, Switzerland.*

9:00 AM - 6:30 PM

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 400 low-redshift group and cluster 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. 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. Here we present a preliminary analysis of the stellar and gas radial profiles for the group and cluster galaxies. We compare with those of the surrounding field galaxies to look for signatures of environmentally-driven gas depletion.

338.16 – **The Effect of Thermal Conduction on the Gas in Galaxy Clusters**

Britton D. Smith[1], B. W. O'Shea[1], M. Voit[1]

[1]*Michigan State University.*
9:00 AM - 6:30 PM

Numerical simulations have provided significant insight into our understanding of galaxy clusters. However, even the most state-of-the-art simulations that include sophisticated treatments of radiative cooling and feedback fail to properly model the intracluster medium. Thermal conduction has been theorized to be very influential in regulating the thermal state in this region, yet due to technical challenges of including this process, the effects have been studied numerically in only a handful of clusters, yielding inconclusive results. We present the results from a series of cosmological simulations of galaxy clusters including isotropic thermal conduction using the Enzo adaptive mesh-refinement + N-body code. We perform simulations including isotropic Spitzer conduction at multiple levels of efficiency. Our computational domain includes a few moderately massive clusters as well as a large number of massive galaxy groups. We investigate the effect of thermal conduction on a variety of galaxy cluster properties, including entropy and temperature profiles; star formation rates; and baryon fractions.

338.17 – **Spectroscopy of Galaxies in Massive SPT Clusters**

Jonathan Ruel[1], M. Bayliss[1], C. Stubbs[1], G. Bazin[2], SPT Collaboration

[1]*Harvard University,* [2]*Universitäts-Sternwarte München, Germany.*
9:00 AM - 6:30 PM

We are in the first year of an NOAO survey program that will yield GMOS-S multi-object spectroscopy of 85 galaxy clusters from the South Pole Telescope (SPT) survey sample, up to a redshift of 0.8. These clusters were selected in mm-wave maps from their Sunyaev-Zeldovich-effect (SZE) signature which is almost independent of the cluster redshift, so that these clusters are the most massive in their part of the sky. Our main goal is to use velocity dispersions, a complementary observable to the gas-based SZE mass proxy, to calibrate the SZE masses and thus improve the constraints on cosmological parameters from the SPT cluster sample. Our spectroscopic sample of around 25 members per cluster will also enable galaxy-property studies, as a legacy data product offered to the community. We present our methodology and first results, as 16 clusters were observed in our first observing season. Funding for this program is provided in part by the NSF.

338.18 – **Simulating the Cooling Flow of Cool-Core Clusters**

Yuan Li[1], G. L. Bryan[1]

[1]*Columbia University.*
9:00 AM - 6:30 PM

We carry out high-resolution adaptive mesh refinement simulation of a cool core cluster, resolving the flow from Mpc scales down to pc scales. We do not (yet) include any heating, focusing instead on the development of the cooling instabilities in order to understand how gas gets to the supermassive black hole (SMBH) at the center of the cluster. We find that, as the gas cools, the cluster develops a very flat temperature profile, undergoing a global cooling instability only in the central 100 pc of the cluster. Outside of this region, the flow is smooth, with no local cooling instabilities, and naturally produces very little low-temperature gas (below a few keV), in agreement with observations. The gas cools and condenses in the very center of the cluster, rapidly forming a thin accretion disk. Isotropic heat conduction does not affect the result, but we show that it is very sensitive to resolution, requiring very high mass resolution to correctly reproduce the small transition radius. The amount of cold gas produced at the very center grows rapidly until a reasonable estimate of the resulting AGN heating rate (assuming even a moderate accretion efficiency) overwhelms cooling. We argue that this naturally produces a thermostat which links the cooling of gas out to 100 kpc with the cold gas accretion in the central 100 pc, potentially closing the loop between cooling and heating.

338.19 – **Comparison of Planck Early Sunyaev-Zel'dovich Catalog Clusters to X-Ray Bright Clusters**

Kevin Fogarty[1]

[1]*Harvard University.*
9:00 AM - 6:30 PM

We use Chandra and XMM-Newton data to compare between the ROSAT brightest cluster sample compiled by Vikhlinin et. al. 2011 and the "Early Sunyaev-Zeldovich" catalog of clusters blindly identified by the Planck observatory. We take the one hundred highest flux (0.1-2.4 KeV) members of the ROSAT sample and one hundred strongest signals from the Planck catalog, as determined by the integrated compton y-parameter reported by Planck, and take a redshift cut of $z < 0.3$. We have examined trends in cluster morphology for these samples, using parameters described in Hudson et. al. 2009 to quantify the cool core structure of the clusters, and in our initial calculation have found that a larger proportion of the x-ray sample appears to have a cool core compared to the Planck sample. We are currently determining how, for the Planck sample, the integrated y-parameter corresponds to the x-ray luminosity and temperature, and how the signals from these two sources relate to physical cluster parameters, particularly morphology. Therefore, we will be adding Chandra results to determine scaling relations as has been previously done with XMM-Newton. We intend, ultimately, to be able to describe the physical reasons for the difference between these two samples.

338.20 – **An XMM-Newton Study of the Core of the Antlia Cluster: Heating and Chemical Enrichment in a Galaxy Cluster without a Cool Core**

William Hawley[1], M. Machacek[2], R. Kraft[2]

[1]*Harvard University,* [2]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

A fundamental question for models of structure formation is how energy and heavy elements are distributed throughout the intra-cluster medium as the cluster evolves hierarchically by sub-cluster mergers along filaments in the cosmic web. The dominant dynamical processes -- hydrodynamic and tidal stripping, supernovae and stellar winds, bulk gas motions induced by mergers, and matter entrainment uplifted by AGN-driven jets and buoyant bubbles -- create distinct X-ray signatures in surface brightness images and temperature and abundance maps of the cluster gas. The relative efficiencies of these processes during the early stages of cluster evolution are not well understood. We present results from a 53 ks XMM-Newton exposure of the inner 12 arcminutes of the Antlia cluster, the nearest example of a galaxy cluster in an intermediate merger stage without a cool core, to the study the merger gas-dynamics. We find a > 20 arcmin (230 kpc) long bridge of enhanced X-ray emission along the line of sight between the two dominant cluster elliptical galaxies (NGC3268 and NGC3258), a sharp edge to the east and south, off-centered from NGC3268, and a bright plume of dense gas rising ~2 arcmin (20 kpc) to the east of NGC3268, inside but twisted relative to the edge, all suggestive of non-hydrostatic gas motions. We measure the density, temperature and abundance of these features to model their origin and constrain simple models for energy and metal transport in the cluster core. We also discuss the properties of a ~5 keV background galaxy cluster (z=0.4-0.5), discovered ~4.8 arcmin to the west of NGC3268 in the XMM field of view.

338.21 – **Population Analysis of Seyfert Galaxies in the Coma-Abell 1367 Supercluster**

Megan Jones[1], E. Wilcots[1]

[1]*UW Madison.*
9:00 AM - 6:30 PM

We are studying the population of active galaxies residing both in and out of groups along the Coma-Abell 1367 supercluster to look at the occurrence of Seyfert galaxies. We report on the distribution of Seyfert galaxies as a function of environment across the supercluster and probe the characteristics of the population of groups that currently host at least one Seyfert. Within the population of the supercluster, we identified ~5% of the galaxies as Seyferts and found that ~40% of the groups contain at least one Seyfert. Only a small fraction of groups contain more than one Seyfert. We also report on the radio emission of selected Seyfert galaxies from the NVSS database, and correlate the properties of the Seyfert population with the HI content of groups as derived in the ALFALFA survey.

338.22 – **Constructing Near UV Composite Luminosity Functions of Galaxy Clusters**

Gustavo A. Morales Correa[1], R. DePropris[2]

[1]*Pontificia Universidad Catolica de Chile, Chile,* [2]*CTIO, Chile.*
9:00 AM - 6:30 PM

We cross match the catalog of nearby clusters of De Propris et al. (2003) with the GALEX archive, to search for clusters with sufficient exposure, in far and near UV, to derive the composite luminosity function at 1500 and 2500 Angstroms. We find 20 such clusters in the database (more will come when the 1/2-sky MIS survey is complete). However, when we match the detections with the SuperCosmos and 2dF databases, we find that several UV bright objects are faint enough to have no detection in the photographic plates and that many of these objects have no redshift. This suggests that, if these objects are cluster members, the majority of the star-forming population in clusters is of low luminosity. We are now exploring statistical subtraction and multi-object spectroscopy for a UV selected sample.

338.23 – **Testing the Standard Model of Cosmology with Strong Lensing Galaxy Clusters**

Matthew Bayliss[1], M. Oguri[2], M. D. Gladders[3], K. Sharon[4], B. Koester[5], M. Gralla[6], C. J. Garcia[7], F. Barrientos[7], M. Carrasco[7]

[1]Harvard-Smithsonian Center for Astrophysics, [2]IMPU, University of Tokyo, Japan, [3]KICP, University of Chicago, [4]Department of Astronomy, University of Michigan, [5]University of Michigan, [6]Department of Physics & Astronomy, Johns Hopkins University, [7]Pontifica Universidad de Catolica, Chile.
9:00 AM - 6:30 PM

Galaxy cluster strong lenses are powerful probes of cosmology, large scale structure, and the high-z universe. They are also, however, extremely rare, and their value has historically been limited as a result of the dearth of known cluster lenses. We present results using a new, well-defined sample of hundreds of galaxy-cluster-scale strong lenses that were identified in the Sloan Digital Sky Survey (SDSS) and the Red-Sequence Cluster Survey 2 (RCS2). We use strong lens model constraints on the matter distribution in the cores of dozens of lensing clusters, and combine these measurements at small radius with multiple mass observables on virial radius scales to empirically recover the mass-concentration relation for clusters spanning more than an order of magnitude in mass. Contrary to previous claims based on small samples of clusters, we find that the mass-concentration relation is generally in good agreement with theoretical expectations for a strong lensing selected sample of clusters. We also use the ensemble statistics of a complete sample of hundreds of giant arcs to provide a new measurement of the abundance of clusters forming giant arcs in a well-defined cosmological volume, and we measure the redshift distribution of our giant arc sample. We find that the median redshift of bright ($g < 24$) giant arcs is $z\sim2$, which provides some relief of the previously claimed "giant arc problem", while simultaneously establishing that our large sample of giant arcs provides the observational community with hundreds of highly magnified galaxies at high redshift.

338.24 – **The Cluster Lensing And Supernova survey with Hubble (CLASH): Weak Lensing from Subaru Observations**

Elinor Medezinski[1], CLASH team

[1]Johns Hopkins University.
9:00 AM - 6:30 PM

The Cluster Lensing And Supernova survey with Hubble (CLASH) is a 524-orbit multi-cycle treasury program to observe 25 galaxy clusters each in 16 broadband filters with WFC3 and ACS. One of the most important drivers of this program is to accurately map the mass distributions of these clusters and to interpret their cosmological implications. Gravitational lensing provides a direct probe of the total mass, regardless of its physical state or composition. A combination of strong lensing (SL) analysis in cluster centers, with weak lensing (WL) analysis that trace the cluster mass out to the virial radius, is required in order to measure cluster mass and its distribution on all scales.

Our wide-field analysis of CLASH clusters utilizes complementary multi-band ground-based Subaru/Suprime-Cam photometry, ideal for WL measurements. By using 5-band photometry we reliably separate the background galaxies for a dilution-free WL measurement, and derive representative 1D/2D mass reconstructions out to the virial radius and robustly measure the cluster dark matter concentrations for several clusters. The full set of 25 clusters will provide unprecedented insights into the mechanisms of structure formation on cluster scale and a test of cosmological models.

338.25 – **Cluster Of Galaxies: Lensing And X-ray Mass Estimates, C-m Relation**

Elena Rasia[1], M. Meneghetti[2], S. Borgani[3], S. Ettori[2]

[1]University of Michigan, [2]Osservatorio di Bologna, Italy, [3]University of Trieste, Italy.
9:00 AM - 6:30 PM

We present a comparison between weak-lensing and X-ray mass estimates of a sample of numerically simulated clusters. The sample consists of 20 massive systems at redhisft $z=0.25$ and virial mass above $5 \times 10^{14}\ M_{sun}\ h^{-1}$. Each cluster has been resimulated at higher resolution and with more complex gas physics. We processed it through through Skylens and X-MAS to create optical and X-ray mock observations along three orthogonal projections. Standard observational tools and methods are used to recover the mass profiles of each cluster projection from the mock catalogues. The resulting mass profiles from lensing and X-ray are individually compared to the input mass distributions to test the reliability of the mass measurements. Given the size of our sample, we could also investigate the dependence of the results on cluster morphology, environment, temperature inhomogeneity, and mass. We confirm previous results showing that lensing masses obtained from the fit of the cluster tangential shear profiles are biased low by 10% and that X-ray masses are affected by both lack of hydrostatic equilibrium and temperature inhomogeneity. The same sample is used to derive the concentration mass relation, that we subsequently compare with the intrinsic one.

338.26 – **HI Deficiency Estimates in Galaxy Group AWM3**

Jaclyn Patterson[1], N. Nichols[1], C. Weigel[1], P. Troischt[1], ALFALFA Team

[1]Hartwick College.
9:00 AM - 6:30 PM

The Undergraduate ALFALFA (Arecibo Legacy Fast ALFA) Team Groups Project is a collaborative undertaking of faculty and students at 11 institutions, aimed at investigating properties of galaxy groups surveyed by the ALFALFA blind HI survey. As part of this project, we examine HI deficiency in the region surrounding galaxy group AWM3 using HI fluxes from ALFALFA and optical data from the Sloan Digital Sky Survey. The galaxy group includes 165 galaxies, of which 66 have 21cm line detections. The HI deficiency calculations reported here are based on comparisons to a sample of 1,624 reference galaxies in low-density environments recently reported by other members of the ALFALFA team. Their sample is taken from the alpha.40 data release and has several advantages over previous HI samples including a large number of high-quality detections and homogeneously measured HI fluxes. It provides a reliable set of reference galaxies for the HI deficiency calculations performed here. This work has been supported by NSF grants AST-0724918, AST-0725267 and AST-0725380.

338.27 – **Group Membership and Dynamical Mass Estimates of Galaxy Group AWM3**

Nathan Nichols[1], J. Patterson[1], C. Weigel[1], P. Troischt[1], ALFALFA Team

[1]Hartwick College.
9:00 AM - 6:30 PM

The Undergraduate ALFALFA (Arecibo Legacy Fast ALFA) Team Groups Project is a collaborative undertaking of faculty and students at 11 institutions, aimed at investigating properties of galaxy groups surveyed by the ALFALFA blind HI survey. As part of this project, we are determining group memberships and developing IDL codes to estimate the corresponding dynamical masses of groups. For galaxy group AWM3, we find a group membership of 165 galaxies, which is used to compare the results from several different dynamical mass calculations. This work has been supported by NSF grants AST-0724918, AST-0725267 and AST-0725380.

338.28 – **Starbursts Versus Stripping: Where Is The Gas In Groups Of Galaxies?**

Lyle Reed[1], C. McGowan[1], A. Micula[1], M. Crone[1], ALFALFA Team

[1]Skidmore College.
9:00 AM - 6:30 PM

We are testing the hypothesis that cool gas is missing in groups of galaxies because it has turned into stars, as opposed to being stripped out of the galaxies by tidal forces or a hot intragroup plasma. To do this, we are examining the properties of galaxies that have been observed using the Sloan Digital Sky Survey (SDSS), the ALFALFA radio survey, and the Spitzer Space Telescope. This combined data set allows us to estimate the amount of “missing” loose gas, the mass in stars, the total mass, and the current star formation rate in each galaxy. We have developed a procedure and accompanying Interactive Data Language (IDL) application to scan known or suspected groups of galaxies. The application reads from the Arecibo General Catalog, automatically queries the online SDSS catalog, selects galaxies for group membership, and calculates the local density near each galaxy.

338.29 – **ALFALFA HI and Star Formation Properties of the NGC 5846 Galaxy Group**

Halley Darling[1], W. Smith[1], L. Viani[1], R. A. Koopmann[1], ALFALFA Team

[1]Union College.
9:00 AM - 6:30 PM

The Undergraduate ALFALFA (Arecibo Legacy Fast ALFA) Team Groups Project is a collaborative undertaking of faculty and undergraduates at 11 institutions, aimed at investigating properties of galaxy groups surveyed by the ALFALFA blind HI survey. The Union College team is analyzing a 9x7 degree region surrounding the galaxy group NGC 5846. We present HI and star formation properties based on analysis of data from the ALFALFA survey, KPNO MOSAIC and CTIO SMARTS 0.9m Halpha imaging, and Sloan Digital Sky Survey spectra. 34% of NGC 5846 group members are detected in HI compared to 60% of galaxies in the environment. Preliminary results indicate that star formation rates are lower in group galaxies. This work has been supported by NSF grants AST-0724918, AST-0725267, and AST-0725380.

338.30 – **Integral Field Unit spectroscopy of Brightest Cluster Galaxies and their companions: Angular Momentum and Dynamical Mass**

James Erickson[1], K. Tran[1], S. Brough[2], K. Gebhardt[3], A. von der Linden[4]

[1]George P. and Cynthia W. Mitchell Institute for Fundamental Physics and Astronomy, Department of Physics and Astronomy, Texas A&M University, [2]Australian Astronomical Observatory, Australia, [3]Department of Astronomy, University of Texas at Austin, [4]Kavli Institute of Particle Astrophysics and Cosmology (KIPAC), Stanford University.
9:00 AM - 6:30 PM

Using the VIMOS Integral Field Unit (IFU) spectrograph on the Very Large Telescope, we are able to map the kinematics of 6 different Brightest Cluster Galaxies (BCGs).

These galaxies are likely to have formed after many mergers and are some of the most massive galaxies we can study. Our sample of BCGs are found at redshifts ranging from z=0.04 to z=0.09. By using velocity dispersion, we are able to measure the dynamical masses for these BCGs, which are on the order of 10^{12} $M_{\odot}$. Using the SAURON λ_R parameter as a measurement of angular momentum, we find the unexpected result that several of the galaxies are strongly rotating, with λ_R as high as 0.5.

338.31 – **Weak Lensing Studies of Mass Substructure in Clusters of Galaxies**

Paul M. Huwe[1]

[1]*Brown University.*
9:00 AM - 6:30 PM

Cluster mass substructure is an important test of the hierarchical model of CDM. We use weak gravitational lensing shear measurements, combined with variable aperture filter methods and PSF correction, to extract information about mass subclumping in HST observations of clusters of galaxies. This work is funded by NASA Rhode Island Space Grant.

339 – Extrasolar Planetary Systems

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

339.01 – **Worlds In Transit: Observations Of Exoplanets TrES-1b, TrES-3b, XO-2b, And GJ-1214b Using IRTF-MORIS**

Mackenzie L. Jones[1], E. R. Adams[2], J. A. Carter[2]

[1]*Butler University,* [2]*Harvard-Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

We present new transits of targets TrES-1b, TrES-3b, XO-2b, and GJ-1214b, observed with IRTF-MORIS. The radius ratio we found for TrES-1b in Sloan r' is 0.131190 +/- 0.000057, which differs by 7 sigma from the Winn et al. (2007) value in z'. A possible cause for this inconsistency is wavelength variation by depth. The other parameters found for TrES-1b were consistent with the Winn et al. (2007) values. The timing for TrES-1b may indicate the need for a new ephemeris. The orbital and planetary parameters found for TrES-3b were consistent with previous values, which can be attributed to good observational conditions and a bright companion star. Likewise, the values found for XO-2b deviated very little from previous literature. Both TrES-3b and XO-2b demonstrated consistent timing values. Due to poor conditions and a lack of good comparison stars within the field of view, the parameter values for the radius ratio, inclination, and orbital distance, found for GJ-1214b are not reliable. The timing values, while still suspect, suggest consistency with the current ephemeris. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

339.03 – **The Impact of Stellar Compositional Anomalies on the Evolution of Stellar Habitable Zones.**

Patrick A. Young[1], K. Liebst[1]

[1]*Arizona State University.*
9:00 AM - 6:30 PM

High quality elemental abundances have been derived from radial velocity planet search spectra for more than a hundred nearby dwarf stars, with more to come. Abundances normalized to iron relative to the sun [X/Fe] vary by more than a factor of two at a given metallicity. We present stellar evolution models generated by the TYCHO code for F, G, and K stars with variations in eight elements (C, O, Na, Al, Mg, Si, Ca, Ti) chosen on the basis of the observed range of variation in nearby stars. The extent of habitable zones around these stars are estimated as a function of time. We find that significant changes in location and lifetime of habitable zones variations accompany abundance ration variations of this magnitude. For oxygen in particular the persistence time of most orbits that are at some point in the habitable zone is shortened by billions of years for high [O/Fe].

339.04 – **Characterizing Extra-Solar Planets with Low Resolution Spectroscopy**

Emily L. Rice[1], B. R. Oppenheimer[2], N. Zimmerman[3], L. C. Roberts, Jr.[4], S. Hinkley[5]

[1]*College of Staten Island,* [2]*American Museum of Natural History,* [3]*Max Planck Institute for Astronomy,* [4]*Jet Propulsion Laboratory, California Institute of Technology,* [5]*California Institute of Technology.*
9:00 AM - 6:30 PM

In the next few years, several high contrast imaging instruments equipped with integral field spectrographs will allow the direct spectral characterization of a variety of companions, from low-mass stars to Jupiter-mass extra-solar planets, at Solar System-like separations (4-40 AU). The spectra obtained by these instruments will be low resolution (R~30-60), making detailed thermo-chemical analysis difficult. Therefore, we have developed a technique that quantitatively compares observed low-resolution spectra with a set of synthetic spectra in order to obtain physical parameters, such as temperature and surface gravity, quickly and robustly. The technique requires no assumptions about age, mass, radius or metallicity of the companion or the primary. We describe this technique and demonstrate its effectiveness with simulated and observed spectra from Project 1640, the high contrast imager and integral field spectrograph on Palomar. The technique can also be used to optimize observing efficiency by determining the ideal wavelength range (for multi-filter instruments such as the Gemini Planet Imager) and signal to noise ratio for a desired precision and accuracy of inferred parameters. The current analysis uses the PHOENIX models as a basis for comparison, but the technique can be applied to any set of models and even used to quantify the differences between models created by different groups. This tool provides a necessary, fast, and comprehensive method of characterizing faint companions of stars, whether they be stellar, sub-stellar or planetary in nature.

339.05 – **Homogeneous Characterization of Transiting Exoplanet Systems**

Yilen Gomez Maqueo Chew[1], F. Faedi[2], L. Hebb[3], D. Pollacco[2], K. G. Stassun[3], S. C. C. Barros[4], L. Ghezzi[5], B. Smalley[6], P. Cargile[3], N. C. Santos[7], S. Sousa[7], C. Mack[3], A. Doyle[6]

[1]*Vanderbilt University/Queen's University Belfast,* [2]*Queen's University Belfast, United Kingdom,* [3]*Vanderbilt University,* [4]*Laboratoire d'Astrophysique de Marseille, France,* [5]*Observatorio Nacional, Brazil,* [6]*Keele University, United Kingdom,* [7]*Universidade do Porto, Portugal.*
9:00 AM - 6:30 PM

We present the analysis of an homogeneous set of high resolution (R > 40,000), high signal-to-noise (S/N > 150) spectra for a large and diverse sample of stars with transiting planets. We consistently derive stellar parameters such as Teff , [Fe/H], log g, and v sin i by using different spectral characterization tools to derive the best parameters with formal and systematic uncertainties. By means of our homogeneous analysis of this high-quality dataset, we are able to investigate any systematic uncertainties on the derived stellar properties, and consequently, on the planetary properties derived from the iterative combination of our spectral analysis with the best available radial velocity data and transit photometry. The resulting consistent set of physical properties allows us to further explore known correlations, e.g., core-size of the planet and stellar metallicity, and to newly identify subtle relationships providing insight into our understanding of planetary formation, structure, and evolution. Our pilot study analyzing our WASP-13 HIRES spectrum (R~48 000, S/N>150) in combination with high precision light curves shows an improvement in the precision of the stellar parameters of 60% in Teff , 75% in [Fe/H], 82% in the stellar mass, and 73% in the stellar radius, which translates into a 64% improvement in the precision of the planetary radius, and more than 2% on the planetary mass, relative to the discovery paper's values.

339.06 – **Grism Spectroscopy Of The Eclipse Of Corot-2b At 1.1-1.7µM**

Ashlee N. Wilkins[1], D. Deming[1], N. Madhusudhan[2], E. Agol[3], A. Burrows[2], D. Charbonneau[4], M. Clampin[5], J. Désert[4], R. Gilliland[6], H. Knutson[7], A. Mandell[5], S. Ranjan[4], S. Seager[8], A. Showman[9]

[1]*University of Maryland,* [2]*Princeton University,* [3]*University of Washington,* [4]*Center for Astrophysics,* [5]*Goddard Space Flight Center,* [6]*Space Telescope Science Institute,* [7]*California Institute of Technology,* [8]*Massachusetts Institute of Technology,* [9]*University of Arizona.*
9:00 AM - 6:30 PM

Here we present HST eclipse spectroscopy spanning 1.1 to 1.7 µm of the CoRoT-2 system using the G141 grism on WFC3. These near-infrared data serve to complement the pre-existing and already-published optical CoRoT data and warm Spitzer infrared observations. CoRoT-2b, the sole planet known in the system, is a member of the Very Hot Jupiter (VHJ) class of exoplanets, and the secondary eclipse was measured with three separate HST visits. We find the albedo of CoRoT-2b upon comparison of optical data, which comprises both thermal and reflected spectral components, and the thermal spectrum as constrained by the Spitzer and WFC3 infrared data. Analysis of the data required characterization of the persistence on the WFC3 detector as it manifests for these observations; it is not insignificant. After compiling results of flux patterns for the majority of the seventeen exoplanets studied in this HST program, we find the extent of the persistence, a linear, additive effect that is strongly dependent upon stimulating flux and time of/since exposure, and subtract it to leave only the true flux received from the CoRoT-2 system in and out of secondary eclipse.

339.07 – **The Effect of Tracking Error on the Measurement of Exoplanet Light Curves**

Brian Graham[1]

[1]*Southridge High School.*
9:00 AM - 6:30 PM

The objective of this project was to determine the effect of telescope tracking error on the quality of exoplanet light curves. Currently, members of the amateur astronomer community are attempting to contribute data towards the characterization of exoplanets in a manner similar to their contributions in the areas of variable stars and asteroids. However, limitations in the available equipment constrain the precision of their measurements. Inconsistencies in telescope tracking can result in blurred images leading to error in the calculations of the host star's relative magnitude. In order to determine the influence that blurred images have on the accuracy of exoplanet light curves, a program was designed and written to analyze images, detect signs of tracking error, and use either a user defined or statistically determined measure of tolerance in order to remove images from the data set. The remaining images were used to calculate a refined light curve. Both the original and refined light curves were compared to the scientifically accepted values. The results indicate a significant correlation between a decrease in the tolerance for tracking error and an increase in the resulting accuracy of the light curve when compared to scientifically accepted values. The images used in the experiment were taken during the transits of HD189733b and of TrES-3b. The software developed for this project has potential applications for those who do not possess equipment capable of taking consistently high quality images. If widely adopted, observations which are based on amateur astronomer data can be more reliable in scientific research.

339.08 – **Detecting The Magnetic Fields Of The Transiting Exoplanets Corot-1b And Wasp-3b**

Jake Turner[1], C. A. Griffith[1], R. Zellem[1], K. K. Hardegree-Ullman[1], L. L. Richardson[1]

[1]*University of Arizona.*
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It is possible to detect the magnetic field of a transiting exoplanet by observing asymmetries in their near-UV and optical light curves (Vidotto et al. 2011). We observed the primary transits of CoRoT-1b and WASP-3b with the Steward Observatory 61" Kuiper Telescope using near-UV and optical filters in order to detect this phenomenon. Preliminary analysis of this data shows an asymmetry between their near-UV and optical ingress times. Future analysis of our data should help provide some of the first constraints on the magnetic fields of transiting exoplanets.

339.09 – **The University of Arizona Astronomy Club Follow-Up Observations of Transiting Extrasolar Planets TrES-3b and TrES-4b**

Amanda Walker-LaFollette[1], J. D. Turner[1], K. K. Hardegree-Ullman[1], B. M. Smart[1], B. E. Crawford[1], T. M. Carleton[1], B. C. Guvenen[1], A. P. M. Towner[1], C. W. Smith[1], L. C. Small[1], A. M. McGraw[1], A. A. Wilson[1]

[1]*University of Arizona.*
9:00 AM - 6:30 PM

It has been suggested by Vidotto et. al. (2011) that it is possible to detect the magnetic field of a transiting exoplanet by comparing near-UV and optical light curve asymmetries. The University of Arizona Astronomy Club has observed the primary transits of extrasolar planets TrES-3b and TrES-4b using near-UV and optical filters in order to detect this phenomenon. One of the goals of this project is to involve undergraduates in observational astronomy research and give them practical experience using IRAF and a research-class telescope. In addition to magnetic field observations, we have refined previously published values for the characteristic parameters of these planets.

339.10 – **How to Flip a Planet or The Kozai Mechanism and Angular Momentum Conservation: Implication for Extrasolar Planets**

Frederic A. Rasio[1], S. Naoz[2], W. Farr[1], Y. Lithwick[1], J. Teyssandier[1]

[1]*Northwestern Univ.,* [2]*Harvard-Smithsonian Center for Astrophysics ITC.*
9:00 AM - 6:30 PM

The theory of secular perturbations between two orbits in a hierarchical triple configuration has many astrophysical applications, from planetary dynamics to triple star systems. In the secular approximation the orbits may change their shape and orientation, but the semi-major axes remain constant. For sufficiently inclined systems, the Kozai mechanism can produce large-amplitude oscillations in the orbital eccentricities and relative inclination. We have re-derived the full set of secular evolution equations including both quadrupole and octupole orders using Hamiltonian perturbation theory. Our new derivation corrects an error in several previous treatments of the problem. We discuss various interesting implications of using the correct formalism for systems containing two coupled planets, including the possibility of forming retrograde planets.

339.11 – **Modeling Capture Probabilities Of Potentially Habitable Exomoons**

Charles Sharzer[1], S. Porter[2], W. Grundy[3]

[1]*Yale University,* [2]*Arizona State University,* [3]*Lowell Observatory.*
9:00 AM - 6:30 PM

The satellites of extrasolar planets (exomoons) have been theorized to be a viable location for extraterrestrial life. New methods are quickly developing to detect their presence by examining the transits of extrasolar gas giants. In addition, models have shown that the probability for a captured exomoon to stabilize into a near-circular orbit at a close distance to a planet is greater than 50 percent. In this study, we model the interaction, potentially resulting in a capture, between a gas giant and a binary moving toward it on a hyperbolic tra jectory. We find that, for certain conditions, capture of an exomoon is not just possible, it is overwhelmingly likely. We hope to use the results of this experiment to determine initial parameters for a subsequent simulation modeling a physical system of a gas giant and binary orbiting a star.

339.12 – **The Initial Mass Distribution For Exoplanetary Systems**

Miles L. Timpe[1], R. Barnes[1], S. N. Raymond[2], N. Gorelick[3]

[1]*University of Washington,* [2]*Laboratoire d'Astrophysique de Bordeaux, France,* [3]*Google, Inc..*
9:00 AM - 6:30 PM

The initial mass distribution for exoplanet systems, prior to the onset of planet-planet scattering, has yet to be adequately constrained. Scattering has previously explained a broad range of observed properties, such as large eccentricities, packing, and mean motion resonances, and hence is a promising theory. We present the results of numerical simulations of scattering-produced multiple planet systems arising from different initial power law mass distributions. Each simulation begins with 5-26 planets on nearly coplanar and circular orbits. We explore which of these power law distributions most accurately reproduces the observed mass distribution, thereby constraining the initial mass function.

339.13 – **The Evolution of Orbital Properties of Exomoons Around Habitable Zone Gas Giant Planets**

Christopher R. Fuse[1]

[1]*Rollins College.*
9:00 AM - 6:30 PM

The Kepler Mission is ideally designed to be able to detect moons of transiting extra-solar giant planets. In February 2011, the Kepler Mission announced some 1200 planet candidates, of which 160 are giant planet candidates. We have performed a computational investigation into the orbital elements of possible systems of exmoons orbiting a Jupiter-sized planet orbiting between 0.5 - 1.5 AU from a parent star.

A disk of proto-moons was allowed to evolve around the giant planet, which has formed in-situ. While many giant planets will have undergone significant migration, we assume the proto-moon disk was actively supplied from an inflow of gas and solids from the circum-giant planet region (Canup & Ward 2002; 2006). The disk simulated represents the last stage of the disk, after inflow has ceased.

We highlight the locations, masses, radii, and other orbital features of the moons surviving after 250,000 years. This is the first in a series of studies on exomoon formation and evolution, which will provide insight into the probable features and locations of exomoons for the Kepler Mission and planet finding missions.

339.14 – **Qatar-2: A K Dwarf Orbited by a Transiting Hot Jupiter and a Longer-Period Massive Planet**

Marta Bryan[1], K. A. Alsubai[2], D. W. Latham[3], S. N. Quinn[3], A. Collier Cameron[4], J. A. Carter[3], L. A. Buchave[5]

[1]*Harvard University,* [2]*Qatar Foundation, Qatar,* [3]*Harvard-Smithsonian CfA,* [4]*SUPA, University of St Andrews, United Kingdom,* [5]*Copenhagen University, Denmark.*
9:00 AM - 6:30 PM

We report the discovery and initial characterization of Qatar-2b, a hot Jupiter transiting a K dwarf in a circular orbit with a short period, P_b = 1.34 days. Differential photometry and model fitting of transit data from both KeplerCam and LCOGT yielded light curve parameters R_P/R_S, a/R_S, u_1, u_2, and i that were optimized using the Markov Chain Monte Carlo technique. Radial velocity measurements from the Tillinghast Reflector Echelle Spectrograph of Qatar-2 over a span of 153 days provided a mass estimate for Qatar-2b, with velocity residuals from the orbital solution that pointed to the presence of a third body in the system. The light curve parameter a/R_S and spectroscopic values for effective temperature and metallicity were used in conjunction with stellar models to estimate the mass and radius of Qatar-2, leading to a mass and radius for Qatar-2b of M_P = 2.54 M_J and R_P = 1.14 R_J, respectively. Next we used the Systemic Console to explore possible orbital solutions for the outer companion, Qatar-2c. Plausible solutions have periods slightly less than a year and a mass of several M_J. However, further observations are needed to determine a reliable orbit for Qatar-2c. Qatar-2 is only the fourth example in the short but growing list of systems with a transiting hot Jupiter and an outer companion. This system architecture is in sharp contrast to that found by *Kepler* for multi-transiting systems, which are dominated by objects smaller than

Neptune, usually with tightly spaced orbits that must be nearly coplanar.

339.15 – **Exploring the Planet-Metallicity Correlation with the Kepler Planet Candidate List**

Catherine A. Pilachowski[1], L. M. Rebull[2], T. R. Monroe[1]

[1]*Indiana University,* [2]*Spitzer Science Center.*

9:00 AM - 6:30 PM

The metallicity distribution of Kepler planet host candidates is explored using metallicities from the Kepler Input Catalog (KIC, Brown et al. 2011). The metallicity distribution of the KIC, with a modal metallicity of [Fe/H] = -0.11 (average [Fe/H] = -0.18, σ=0.28 dex) is similar to the metallicity distribution of stars in the solar neighborhood from Holmberg et al. (2007), with a modal metallicity at [Fe/H] = -0.09 (average [Fe/H] = -0.15, σ = 0.20 dex), suggesting that the metallicities reported in the KIC are of sufficient accuracy to provide useful information about the metallicity distribution of planet hosts. Candidate planet hosts with temperatures cooler than 4000K have been eliminated, as have candidate hosts with metallicities below [Fe/H] = -1.0, because of uncertainties in the KIC metallicity calibration. Candidate hosts with multiple planets have only been included once, based on the most massive planet candidate. Sorting the planet host candidates by the size of the largest planet candidate, we find average KIC metallicities of stars hosting candidate Earth size planets to be [Fe/H] = -0.24 +/- 0.04; of stars hosting candidate super Earth planets to be [Fe/H] = -0.15 +/- 0.02; of stars hosting candidate Neptune size planets to be -0.14 +/- 0.01; of stars hosting candidate Jupiter size planets to be [Fe/H] = -0.090 +/- 0.02; and of stars hosting candidate super Jupiter size planets to be [Fe/H] = -0.013 +/- 0.04. The errors are standard error of the mean. The average metallicity of a planet host appears to increase with planet size, suggesting that stars with higher metallicity are more likely to make large planets, but that lower metallicity stars are as likely as metal-rich stars to make smaller planets.

339.16 – **Stellar Abundances and Planet Formation: The Case of 16 Cyg A & B**

Simon C. Schuler[1], K. Cunha[1], V. V. Smith[1], L. Ghezzi[2], J. R. King[3], C. P. Deliyannis[4], A. M. Boesgaard[5]

[1]*NOAO,* [2]*Observatório Nacional, Brazil,* [3]*Clemson University,* [4]*Indiana University,* [5]*University of Hawaii.*

9:00 AM - 6:30 PM

We present the results of a detailed abundance analysis of the solar twins 16 Cyg A and 16 Cyg B based on Keck/HIRES spectroscopy. 16 Cygni is a triple star system with the two solar-twin primary stars and a proper-motion M dwarf companion of 16 Cyg A. 16 Cyg B is known to host a giant planet on an eccentric orbit (e=0.69) while no planets have yet been detected around 16 Cyg A. The abundances of 15 elements have been derived and are found to be indistinguishable between the two stars. The abundances of each element differ by <= 0.026 dex, and the mean abundance difference is +0.003 +/- 0.015 (sigma) dex. Aside from Li, which has been previously shown to be depleted by a factor of at least 4.5 in 16 Cyg B relative to 16 Cyg A, the two stars appear to be chemically identical. The physical characteristics of the 16 Cyg system are discussed in terms of planet formation models, and a consistent scenario that can account for the lack of detected planets around 16 Cyg A, the disparate Li abundances of 16 Cyg A and B, and the eccentricity of the planet 16 Cyg B b is presented.

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340 – Evolution of Galaxies II

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

340.01 – **The Galaxy Evolution Explorer (GALEX) Source Catalogs**

Mark Seibert[1], T. Wyder[2], J. Neill[2], B. Madore[1], L. Bianchi[3], M. Smith[4], B. Shiao[4], D. Schiminovich[5], R. M. Rich[6], T. Conrow[2], D. C. Martin[2], GALEX Catalog Team

[1]*Carnegie Institution of Science,* [2]*Caltech,* [3]*Johns Hopkins University,* [4]*Space Telescope Science Institute,* [5]*Columbia University,* [6]*UCLA.*

9:00 AM - 6:30 PM

We present the Galaxy Evolution Explorer (GALEX) All-Sky Survey Source Catalog (GASC) and the GALEX Medium Imaging Survey Source Catalog (GMSC) derived from the GALEX GR6 data release. These catalogs provide vetted and unique measurements of point and extended sources up to 1 arcminute diameter in the GALEX NUV (2300 Angstroms) and FUV (1500 Angstroms) bands. A principal goal for the project is to ensure that the research community has access to high quality measurements of the enormous volume of GALEX imaging data. Our intention is that the catalogs will serve as the official GALEX reference for cross matching to other surveys such as WISE, SDSS, and 2MASS. The GASC and GMSC are defined by NUV detections, which typically have significantly higher S/N than the FUV. The GASC and GMSC report FUV fluxes within NUV defined apertures for those regions with FUV observations. Covering a total of 26,300 deg^2 of sky, the GASC consists of all GALEX observations with exposure times below 800 sec and reaches a depth of NUV ~21 (AB mag). The GMSC covers a smaller region of 5000 deg^2 with exposure times between 800 and 10,000 sec and reaches a depth of NUV ~23 mag. There are a total of 40 million unique sources in the GASC and 22 million in the GMSC. Each catalog is accompanied by exposure time, coverage and flag maps in FITS and Healpix formats. We have also quantified the completeness, reliability, and astrometric uncertainties of both catalogs. Users will be able to access the catalogs through the Multi-mission Archive at the Space Telescope Science Institute (MAST) and eventually through the NASA Extragalactic Database. The images and footprint files will be made available from MAST as well.

340.02 – **Regulating Star Formation by Molecular Hydrogen in Cosmological SPH Simulations**

Robert Thompson[1], K. Nagamine[1]

[1]*University of Nevada Las Vegas.*

9:00 AM - 6:30 PM

It has been shown that star formation correlates tightly with molecular hydrogen. We track the molecular hydrogen mass fraction within our cosmological SPH code GADGET-3 by use of a semi-analytical model by Krumholz et al. that assumes a formation-dissociation balance. This model allows us to regulate the star formation in our simulation by the local abundance of molecular hydrogen rather than a gas surface density threshold. We investigate implications of the H_2 star formation model on high-redshift galaxy population properties such as mass/luminosity function.

340.03 – **Steep Faint-end Slopes of Galaxy Mass and Luminosity Functions at z ≥ 6 in Cosmological SPH Simulations and the Implications for Reionization**

Jason Jaacks[1], J. Choi[2], K. Nagamine[1]

[1]*University of Nevada Las Vegas,* [2]*University of Kentucky.*

9:00 AM - 6:30 PM

We present the results of a numerical study comparing photometric and physical properties of simulated z = 6 − 9 galaxies to the observations taken by the WFC3 instrument aboard the Hubble Space Telescope. Using cosmological hydrodynamical simulations we find good agreement with observations in color-color space at all studied redshifts. We also find good agreement between observations and our Schechter luminosity function fit in the observable range, Muv ≤ −18. However beyond what currently can be observed, simulations predict a very large number of low-mass galaxies and evolving steep faint-end slopes from $\alpha_L = -2.15$ at z = 6 to $\alpha_L = -2.64$ at z = 9, with a dependence of $|\alpha_L| \propto (1+z)^{0.59}$. During the same epoch, the normalization φ* increases and the characteristic magnitude Muv becomes moderately brighter with decreasing redshift. We find similar trends for galaxy stellar mass function with evolving low mass end slope from $\alpha_M = -2.26$ at z=6 to $\alpha_M = -2.87$ at z=9, with a dependence of $|\alpha_M| \propto (1 + z)^{0.65}$. We also find that the low mass halos ($M_h < 10^{10}$ M*) in our simulations produce higher luminosity than predicted by semi-analytic models that are calibrated by the observed luminosity function at z=6. Together with our recent result on the high escape fraction of ionizing photons for low-mass galaxies, our results suggest that the low-mass galaxies are important contributor of ionizing photons for the reionization of the Universe at z ≥ 6.

340.04 – **Semi-automated Search For Lyman-alpha And Other Emission Lines In The DEEP2 And DEEP3 Databases**

Katherine McCormick[1], A. Alvarez-Buylla[2], V. Dean[3], P. Guhathakurta[1], K. Lai[1], M. Sawicki[4], B. Lemaux[5], C. Grishaw-Jones[6], DEEP2, DEEP3

[1]*UCSC,* [2]*Balboa High School,* [3]*Castilleja High School,* [4]*Saint Mary's University, Canada,* [5]*UCD,* [6]*Santa Cruz High School.*

9:00 AM - 6:30 PM

The DEEP2 and DEEP3 redshift surveys have obtained spectra of approximately 75,000 distant galaxies. In an effort to obtain as much information as possible from these spectra, we have performed a semi-automated, systematic search for emission lines in the DEEP2 and DEEP3 databases. The process is a two-step one: first, we run the SExtractor software on sky-subtracted 2D DEIMOS spectra to find emission lines and we categorize these emission lines based on whether they are associated with the target galaxy, single emission lines, possible artifacts resulting from poorly subtracted night sky emission lines, etc. Next, we supplement the automated search with both a guided and an unguided visual search and compare our findings with the output of the program. During this visual inspection process, we check the program for completeness and contamination. By introducing an automated element to the search we have compiled a more objective and complete census of the emission lines in the DEEP2 and DEEP3 databases than a pure visual search would yield. Our program has detected some faint

emission lines that had been missed by the human eye. In addition, through our semi-automated search, we have located several possible serendipitous high redshift Lyman-alpha emitting galaxies in the redshift range of 3 to 7. This research was funded by the NSF and the Science Internship Program (SIP) at UCSC.

340.05 – **EWs, Escape Fractions & Kinematics of Lyα Emitters in COSMOS at 4 < z < 6**

Ryan P. Mallery[1], B. Mobasher[1], P. Capak[2], D. Masters[1], Y. Kakazu[2], O. Ilbert[3], C. Scarlata[4], M. Salvato[5], N. Scoville[2]

[1]UC Riverside, [2]California Institute of Technology, [3]Laboratoire d'Astrophysique de Marseille, France, [4]University of Minnesota, [5]Max-Planck-Institut für Astronomie, Germany.

9:00 AM - 6:30 PM

We investigate spectroscopically measured Lyα equivalent widths and escape fractions of 241 sources at 4<z<6 of which 95 are BJ, g+, VJ, r+, i+ dropout selected sources and 106 are from three narrow band selected samples of Lyα emitters (LAEs) at z~4.2, z~4.8, and z~5.6. The sources were selected from the Cosmic Origins Evolution Survey (COSMOS), and observed with the DEIMOS spectrograph. We find that the distribution of equivalent widths increases with redshift for both the dropout selected sources and the narrow-band selected sources. We also find that the Lyα escape fraction of narrow band LAEs is on average higher and has a larger variation than the escape fraction of dropout selected sources. The escape fraction does not show a dependence with redshift. Similar to what has been found for LAEs at low redshifts, the sources with the highest extinctions show the lowest escape fractions. The range of escape fractions increases with decreasing extinction. This is evidence that the dust extinction is the most important factor affecting the escape of Lyα photons, but at low extinctions other factors such as HI covering fraction and gas kinematics can be just as effective at inhibiting the escape of Lyα photons. Co-added spectra were created for each of the sub-samples of dropouts and narrow-band sources. We detect blue-shifts of low ionization interstellar absorption features with respect to the Lyα emission which we interpret as evidence of outflows.

The velocity offset is found to decrease with redshift for both dropout selected sources and narrow-band selected sources. We also find a weak trend for the mean Lyα EW for the sources in each co-added to decrease as the outflow velocity increase, and a weak trend of increasing mean Lyα FWHM increasing outflow velocity.

340.06 – **Is There Diffuse Lyman-alpha Emission Around Lyman-alpha Galaxies?**

Brent Mathew Smith[1], S. Malhotra[1], J. Rhoads[1], S. Finkelstein[2], Z. Zheng[3], J. Wang[3]

[1]Arizona State University, [2]University of Texas, Austin, [3]USTC, China.

9:00 AM - 6:30 PM

The Lyman alpha line is resonantly scattered, thus neutral gas within a galaxy can scatter these photons out into a diffuse halo. Understanding what fraction of the Lyman alpha photons do not make it directly out of the central galaxy is crucial to interpret high-redshift spectroscopic detections, or lack thereof, of Lyman alpha. However, thus far these halos have only been observed in a few instances. We study these halos at z=4.5 by coadding narrow-band images containing the Lyman-alpha emission line for a sample of ~ 200 spectroscopically confirmed Lyman-alpha galaxies. Thus stacking allows us to probe to very faint surface brightness levels. We compare the Lyman alpha surface brightness distribution of Lyman-alpha-selected galaxies with Lyman-break galaxies to see if these two samples differ in their general nature.

340.07 – **Probing the Rest-Frame Optical Continuum of z=4.5 Lyman Alpha Emitters with Spitzer**

Keely D. Finkelstein[1], S. Malhotra[2], J. E. Rhoads[2], S. L. Finkelstein[1], V. Tilvi[3], N. A. Grogin[4], N. Pirzkal[4], A. Dey[5], B. T. Jannuzi[5], B. Mobasher[6], S. Pakzad[5], J. Wang[7]

[1]University of Texas Austin, [2]Arizona State University, [3]Texas A&M University, [4]Space Telescope Science Institute, [5]National Optical Astronomy Observatory, [6]University of California, Riverside, [7]University of Science and Technology of China, China.

9:00 AM - 6:30 PM

We present the results from a deep Spitzer Space Telescope survey of more than 100 Lyman alpha emitters (LAEs) at z~4.5, first discovered in the Bootes field of the Large Area Lyman Alpha (LALA) survey. These Spitzer/IRAC observations probe the rest-frame optical continuum emission of these galaxies. We also have in hand NICMOS and WFC3 near-infrared (NIR) data from the Hubble Space Telescope (HST) of a sub-sample of these same galaxies. Of the more than 100 sources targeted with Spitzer, 15 sources are detected in at least two out of the four NICMOS/WFC3 and IRAC bands (1.1, 1.6, 3.6 and 4.5 microns), while another ~ 40 sources are detected in one band. We will present the results from a SED-fitting analysis, using the suite of data in the observed NIR/mid-IR, coupled with deep ground based optical data. LAEs form the faint end of the galaxy luminosity function, thus most studies rely on stacking to constrain the rest-frame optical light, which can wash out variations in the physical properties in individual LAEs. This is the largest sample to date of high-redshift LAEs with measured NIR/IR fluxes, allowing us to place the most robust constraints yet on the spread of physical properties in the LAE population.

340.08 – **The Evolution of the Rest-frame V-band Luminosity Function from z=4: A Constant Faint-end Slope over the Last 12 Gyr of Cosmic History**

Danilo Marchesini[1], M. Stefanon[2]

[1]Tufts University, [2]Observatori Astronomic Universitat de Valencia, Spain.

9:00 AM - 6:30 PM

We present the rest-frame V-band luminosity function (LF) of galaxies at $0.4 \leq z < 4.0$, measured from a near-infrared selected sample constructed from the NMBS, the FIRES, the GOODS-CDFS FIREWORKS, the ultra-deep NICMOS observations in the HDFN, and the ultra-deep WFC3 observations in the HUDF and GOODS-South, all having very high-quality optical to mid-infrared data. This sample is unique in that it combines data from surveys with a large range of depths and areas in a self-consistent way, allowing us to (1) minimize the uncertainties due to cosmic variance; and (2) simultaneously constrain the bright and faint ends over the entire targeted redshift range, probing the LF down to 0.02L* at $z \sim 3$. We find that (1) the faint-end slope is fairly flat and constant from z=4, with $\alpha = -1.27 \pm 0.04$; (2) the characteristic magnitude has dimmed by 1.3 mag from $z \sim 3.7$ to z=0.1; (3) the characteristic density has increased by a factor of ~8 from $z \sim 3.7$ to z=0.1; and (4) the luminosity density peaks at $z \approx 1-1.5$, increasing by a factor of ~4 from z=4.0 to $z \approx$1-1.5, and subsequently decreasing to z=0.1 by a factor of ~1.5. We find no evidence for a steepening of the rest-frame optical faint-end slope with redshift out to z=4, in contrast with previous observational claims and theoretical predictions. This suggests that the stellar feedback efficiency, responsible for shaping the faint end, might evolve with time (being larger at earlier times) to compensate for the steepening with redshift of the dark matter halo mass function slope.

We gratefully acknowledge grant support for this research from programs HST-AR-11764 and HST-AR-12141, provided by NASA.

340.09 – **Properties of High Equivalent Width Lyman-α Emitting Galaxies at Redshifts Between 2.5 and 3.5**

Brian J. Baptista[1], D. Bonfield[2], C. Grady[3], D. Lindler[3], S. Mufson[1], B. Woodgate[3]

[1]Indiana University, [2]University of Hertfordshire, United Kingdom, [3]NASA/Goddard Space Flight Center.

9:00 AM - 6:30 PM

Lyman-α emitting galaxies (LAEs) have been studied for the last decade, yet there are few observations of high equivalent width (EW) objects. The emission mechanisms that drive high EW LAEs, though studied for the last decade, still are not well understood. Since only small numbers have been discovered, it is unknown whether these high EW LAEs make up a population that is undergoing a peculiar stage of galactic evolution, or simply just a more vigorous version of star formation coupled with a clumpy ISM. We have developed a broadband selection technique to effectively increase the number of known LAEs, to build a bigger sample of high EW LAEs. While these high EW LAEs are less numerous than typical LAEs, we are able to probe much larger volumes than blind narrowband or spectroscopic searches. Using photometry from the Deep 2 and 3 fields from the CFHT-Legacy Survey, we have spectroscopically confirmed 63 LAEs with redshifts between 2.5 and 3.5 using the WIYN/Hydra multi-object spectrograph. These LAEs exhibit narrow Lyman-α emission, and show no other line emission to our spectroscopic flux limits. Using UV continuum fitting techniques in conjunction with our spectroscopic data, we have calculated equivalent widths, star formation rates, internal reddening, and escape fractions for our program galaxies. Of the 63 LAEs that we discovered, 29 show EWs that are in excess of 100 Å in the rest frame.

340.10 – **Present-day Descendants of z=3.1 Lyα Emitting Galaxies In The Millennium-II Halo Merger Trees**

Jean P. Walker[1], E. Gawiser[1], N. A. Bond[2], N. Padilla[3], H. Francke[3]

[1]Rutgers University, [2]NASA Goddard Space Flight Center, [3]Pontificia Universidad Católica de Chile, Chile.

9:00 AM - 6:30 PM

We use the Millennium-II N-body simulation to study the z=0 descendants of Lyman Alpha Emitters (LAEs) at z=3.1. The N-body simulations present us with the possibility to study galaxy evolution using dark matter halo merger trees. Several models for connecting LAEs with their host dark matter halos are used to produce mock catalogs of galaxies at z=3.1 that have clustering bias matching the measured bias of z=3.1 LAEs. The merger trees then give us the dark matter masses of the descendants at z=2.1, z=1 and z=0. We find that our model LAEs' median halo mass increases from $10^{10.9}$ M_{sun} at z=3.1 to $10^{11.3}$ M_{sun} at z=2.1, $10^{11.9}$ M_{sun} at z=1 and $10^{12.7}$ M_{sun} at z=0. The uncertainty in the median halo mass at z=0 due to the uncertainty in the measured z=3.1 bias is a factor of seven. The simulated median halo masses at z=2.1 suggest that the typical z=3.1 LAE evolves into an LAE at z=2.1. The median present-day descendant of our mock catalogs has a dark matter halo mass a few times higher than an L* galaxy, but for the 55% of descendant halos that are central rather

than satellite galaxies, the median dark matter halo mass is close to that of the Milky Way.

340.11 – **Exploring the Photometric Properties of z=3.1 Lyman Alpha Emitting Galaxies**

Carlos Vargas[1], V. Acquaviva[1], E. Gawiser[1], K. Lai[2], MUSYC Collaboration

[1]Rutgers University, [2]Harvard-Smithsonian Center for Astrophysics.

9:00 AM - 6:30 PM

Using a sample of 162 Lyman Alpha emitting galaxies (LAEs) at z=3.1 discovered by the MUSYC collaboration (Gronwall et al. 2007), we analyze photometric properties of stacked galaxy images. We also analyze the photometry of stacked sub-samples published by Lai et al. (2008) that are either detected or undetected in the Spitzer-IRAC 3.6 micron band. Obtaining photometry on stacked images of these samples helps to reveal characteristics of our universe at high redshift via Spectral Energy Distribution (SED) fitting. The photometric properties of these samples are then compared with those of individual LAEs bright enough to enable fitting of their SEDs, casting further light on the nature of these precursors to Milky-Way type galaxies.

340.12 – **Individual And Rest-frame Composite Spectra Of Lyα Emitting And Uv Continuum-selected Galaxies At 2<z<3.5**

Michael Berry[1], E. Gawiser[1], L. Guaita[2], N. Padilla[3], E. Treister[4]

[1]Rutgers University, [2]Stockholm University, Sweden, [3]Universidad Católica de Chile, Chile, [4]Universidad Concepcion in Chile, Chile.

9:00 AM - 6:30 PM

We present properties of individual and composite spectra of continuum- and narrowband-selected star-forming galaxies (SFGs) at a redshift of 2<z<3.5 discovered by the MUSYC collaboration in the Extended Chandra Deep Field-South. Among our dataset of 82 SFGs, 59 have R<25.5 of which 32 have rest-frame $W_{Ly\alpha}$>20Å, the canonical limit to be classified as a Lyα emitting galaxy (LAE). We divide our dataset into subsamples based on properties we are able to measure for each individual galaxy: Lyα emission, rest-frame UV colors, and redshift. Among our subsample of galaxies with R<25.5, those with rest-frame $W_{Ly\alpha}$>20Å have bluer UV continua, weaker low-ionization absorption lines, weaker C IV absorption, and stronger Si II* emission than those with $W_{Ly\alpha}$<20Å. We measure a velocity offset of Δv~600 km/s between Lyα emission and interstellar absorption, which does not appear to vary substantially between the two subsamples. Through dividing the sample based on photometric colors whereby they are parameterized to represent intrinsic UV spectral slopes, we find that galaxies with bluer spectral slopes have stronger Lyα emission, weaker low-ionization absorption and more prominent nebular emission line profiles.

340.13 – **The Lbt Bootes Field Survey: Luminosity Function And Clustering Of Z~3 Lbgs At The Bright End.**

Fuyan Bian[1], X. Fan[1], L. Jiang[2], A. Dey[3], R. F. Green[1], R. Maiolino[4], F. Walter[5], S. Jester[6], K. Lee[7], I. Mcgreer[1]

[1]University of Arizona, [2]Arizona State University, [3]National Optical Astronomy Observatory, [4]INAF, Italy, [5]Max Planck Institute for Astronomy, Germany, [6]Max Planck Institute for Astronomy, Germany, [7]Purdue University.

9:00 AM - 6:30 PM

We present deep U band imaging data covering an area of 9 Square deg in the NOAO Deep Wide-Field Survey (NDWFS) Bootes fields. The data were takenby the Large Binocular Camera (LBC) on the 2x8.4-m Large Binocular Telescope (LBT). Combined with deep Bw and R-band images from NWDFS, we selected ~15,000 Lyman Break Galaxy (LBG) candidates at z down to R=25.5 in the entire Bootes Field, the largest z~3 LBG sample in existence. Using this sample, the rest-frame UV and near-IR luminosity functions (LFs) of the LBGs is measured. The large survey area also helps us to eliminate the cosmic variance and put strong constraint on the bright end of the LFs. The spatial distributions of two bright LBG samples (23.5<R<24.0 and 24.0<R<24.5) are studied. The comoving correlation lengths increase with the R band brightness, implying that the clustering strength increases with rest-frame UV luminosities.

340.14 – **Understanding The Nature Of Massive Starburst Galaxies Through Cosmic Times**

Dominik A. Riechers[1]

[1]California Institute of Technology.

9:00 AM - 6:30 PM

Over the past decade, we have made great progress in studies of submillimeter galaxies (SMGs), which suggest that they represent a population of massive intense dusty starbursts at early cosmic times. SMGs are thought to be the progenitors of massive spheroidal galaxies at present day. Studies out to the largest cosmic distances are of key importance, because massive galaxies in the early universe are expected to grow in the densest peaks. This makes them ideal signposts of proto-cluster environments, back to the first billion years. Unfortunately, observational limitations in the past, in particular the requirement of a radio continuum counterpart and the requirement of optical redshifts (both of which are non-trivial to obtain for this extremely dusty galaxy population), have led to a considerable failure rate in correct identifications. These limitations thus yielded an incomplete understanding of the nature and physical properties of the SMG population as a whole. We here describe how direct identification of Herschel-selected SMGs through molecular and far-infrared fine structure emission lines help to overcome these limitations, yielding a more unbiased picture of the most intense massive starburst galaxies in the universe.

340.15 – **A MOSAIC Search for Lyman Alpha Emitting Galaxies at z~2.1**

Patrick Williams[1], S. Finkelstein[2], J. Rhoads[3], E. McLinden[3], S. Malhotra[3]

[1]Texas A&M University, [2]University of Texas, [3]Arizona State University.

9:00 AM - 6:30 PM

Lyman Alpha Emitting Galaxies (LAEs) are extremely important in the study of galaxy evolution as their clustering indicates that they are the likely progenitors of Milky-Way size galaxies in the local Universe. Although observations of LAEs at $3.1 < z < 6$ indicate very little evolution of the luminosity function (LF), separate observations at z~0.3 indicate that low-redshift LAEs are both rarer and fainter. We use narrow-band imaging to select LAEs at an intermediate redshift of z~2.1 to search for evolution in the range of $0.3 < z < 3.1$. The data sets consisted of images gathered from three separate observing runs spanning three years at the Kitt Peak National Observatory (KPNO) and Cerro Tololo Inter-American Observatory (CTIO). In addition to standard reduction techniques, we used specifically designed reduction tasks for the MOSAIC camera at KPNO and CTIO in order to combine our final reduced images into a single stacked image. This deep, stacked image will aid us in detecting LAEs at our chosen redshift of z~2.1. Using this sample at z~2.1, we hope to investigate certain evolutionary properties of LAEs including age, stellar mass, dust and dark matter halo mass. We will present a status update on this project, including our initial sample of z~2.1 LAEs.

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341 – Star Formation

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

341.01 – **Probing Turbulence in Regions of Star Formation Using H2O and CH3OH Masers**

Naomi Alpert[1]

[1]*Vassar College, Maria Mitchell Observatory.*
9:00 AM - 6:30 PM

The VLBI maps of H2O and CH3OH masers were used to study the statistical properties of velocity and spatial distribution of gas in three regions of star formation: G23.01-0.41, G16.59-0.05, and IRAS 20126+4104. For all sources there appears to be a combination of turbulent and regular components of motion, the latter prevailing at larger scales. At smaller scales, the statistical properties of the velocity field and spatial distribution indicate turbulent motion. In particular, [1] the two-point line-of-sight velocity correlation function is satisfactorily approximated by a power law with the exponent close to Kolmogorov's (1/3), and [2] the angular distribution of the maser spots demonstrates self-similarity over 2-3 orders in scale, and the calculated fractal dimension is significantly less than 2, which implies highly intermittent turbulence. This project was supported by NSF/REU grant AST-0851892 and the Nantucket Maria Mitchell Association.

341.02 – **Magnetic Fields in Star Forming Regions: A GPIPS Study**

Robert C. Marchwinski[1], M. D. Pavel[1], D. P. Clemens[1]

[1]*Boston University.*
9:00 AM - 6:30 PM

We present early results from a statistical analysis of magnetic field strengths in star forming regions revealed by data from the Galactic Plane Infrared Polarization Survey (GPIPS). Ten star forming regions were chosen for analysis based on GLIMPSE and BOLOCAM survey properties. All targets are in the first galactic quadrant at estimated distances between 2.35 and 4.05 kpc. Background starlight polarization data were obtained with the Mimir instrument on the 1.8m Perkins telescope outside Flagstaff, AZ. Starlight polarizations were mapped in and around the star-forming clouds, and the Chandrasekhar-Fermi method was used to create resolved magnetic field strength maps with up to 22 arcsec resolution. Regions offset from the star formation provide context for assessing the effects of star formation on, and by, magnetic fields. Our previous study of the quiescent cloud GRSMC 45.60+0.30 was used for comparison with these star forming regions. Key future questions which exist for exploration with this data set include: How well do GPIPS polarizations probe dense cores surrounding newly forming stars? How does the magnetic field strength change around the cores? How do magnetic field strengths and gas densities relate in the regions surrounding cores? This work was partially supported by NSF AST 09-07790, Federal Work-Study, and Boston University Undergraduate Research Opportunity Program grants and awards.

341.04 – **Water Masers in Star Forming Regions of the Large Magellanic Cloud**

Kamber R. Schwarz[1], J. Ott[2], D. Meier[3], M. Claussen[2]

[1]*NRAO and University of Arizona,* [2]*NRAO,* [3]*New Mexico Institute of Mining and Technology.*
9:00 AM - 6:30 PM

We present the results of a survey of star forming regions in the Large Magellanic Cloud for water maser emission conducted at the Australia Telescope Compact Array. For our 37 pointings a total of 27 masers where detected. 20 of these are, as far as we are able to determine, new detections. The properties and relationships between the masers and their surroundings are examined and compared to similar environments in the Milky Way. The LMC masers tend to be associated with young stellar objects and there is a weak correlation between maser and YSO luminosity. Similar correlations have been found for masers in the Milky Way. However, the LMC water masers tend to be less luminous than their Milky Way counterparts.

The NRAO is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc. Part of this research was carried out under the auspices of the National Science Foundation's Research Experience for Undergraduates (REU) program at the NRAO, and we gratefully acknowledge the funding for this program.

341.05 – **The Structure of Accretion Flows in the Formation of Very Massive Stars**

Roberto Galvan-Madrid[1], Q. Zhang[2], E. Keto[2], L. F. Rodriguez[3], P. T. Ho[4]

[1]*ESO, Germany,* [2]*Harvard-Smithsonian CfA,* [3]*UNAM, Mexico,* [4]*ASIAA, Taiwan.*
9:00 AM - 6:30 PM

We present multi-configuration Submillimeter Array (SMA) observations toward a small sample of very luminous ($L > 10^5$ L_{sun}) massive star formation regions. Dense, warm molecular gas is detected surrounding Hypercompact HII regions. The physical structure and dynamics of these accretion flows is resolved down to < 0.05 pc using a combination of molecular and hydrogen recombination lines. Massive, partially-ionized accretion flows appear to be the birthplace of the most massive ($M > 15$ M_{sun}) stars in the Galaxy.

341.06 – **Molecular Line Predictions of Embedded Super Star Cluster Envelopes**

David G. Whelan[1], K. E. Johnson[1], R. Indebetouw[1]

[1]*University of Virginia.*
9:00 AM - 6:30 PM

A new era in millimeter-wave astronomy is opening up with the advent of Early Science at the Atacama Large Millimeter/sub-millimeter Array (ALMA). The completed array will have the sensitivity and resolution to observe many objects that are too small or too faint to observe with other facilities. One such class of objects is the embedded super star clusters - compact, massive, young star clusters in the very act of forming. In preparation for ALMA, we present predictions of molecular line strengths from the embedding envelopes around brand-new super star clusters. Following up on the dust radiative transfer models of Whelan et al. (2011), the envelope geometry is spherically symmetric. Only smooth dust distributions are computed for, leaving the testing of clumpy geometric effects for a future study. A variety of envelope density profiles are tested. Photodissociation region (PDR) models are run to determine molecular species abundances throughout the envelope, and line luminosities for CO and HCN are computed using a line radiative transfer code. Results are compared to galaxies presented in Gao & Solomon (2004) and Galactic molecular clouds in Wu et al. (2010).

341.07 – **Molecular Line Studies of Serpens South Star Forming Region**

Lia Medeiros[1], R. Friesen[1], S. Schnee[1], R. Gutermuth[2], T. Bourke[3], P. Myers[3], J. Di Francesco[4]

[1]*NRAO,* [2]*Smith College,* [3]*Harvard Smithsonian Center for Astrophysics,* [4]*NRC-HIA, Canada.*
9:00 AM - 6:30 PM

We present findings from an ammonia molecular line study of the Serpens South star-forming cluster, within the Serpens molecular cloud, performed using the K-band Focal Plane Array at the GBT. We have mapped a 40' by 30' area in the NH3 (1,1), (2,2) and (3,3) inversion transitions, as well as in HC7N 21-20. The NH3 (1,1) and (2,2) emission was used to derive kinetic temperatures across the region, which range from 7.5 K to 17.5 K. Despite a 10 K range of temperature for NH3, all of the HC7N was found within the 2 K range of 9.5 K and 11.5 K. We find the distribution of both molecules throughout the cloud is different, although the line-of-sight velocities agree well. The HC7N emission peaks do not coincide with peaks in NH3 emission, and we additionally find HC7N in areas with very low NH3 abundance. Where present, the abundance of HC7N is broadly consistent with previous studies of other carbon chain producing regions. Finally, we find self-absorbed HC7N emission towards several dense cores, with line profiles suggesting both infall and outflow motions. We fit the line profiles to determine infall and outflow velocities for these regions.

341.08 – **The Stellar Content of Intermediate-Mass Star-Forming Regions.**

Michael Lundquist[1], H. Kobulnicky[1], M. Alexander[1], C. Vargas Alvarez[1], K. Arvidsson[2], C. Kerton[3]

[1]*University of Wyoming, Physics & Astronomy,* [2]*Adler Planetarium,* [3]*Iowa State University, Physics & Astronomy.*
9:00 AM - 6:30 PM

In an effort to understand the factors that govern the transition from low- to high-mass star formation, we report near-infrared imaging and spectroscopy of stars within a sample of intermediate-mass star-forming regions (IMSFRs). Some IMSFRs appear to contain compact <1 pc embedded clusters at an early evolutionary stage similar to compact HII regions, but lacking the massive ionizing central star(s). The IMSFRs have photodissociation regions with diameters ~1 pc powered by the equivalent of an early B star, but because all sources lack radio free-free emission, they must host a collection of less massive stars. These spectroscopic observations using FLAMINGOS on the Kitt Peak 4 m telescope, coupled with 2MASS and UKIDSS infrared imaging, identify which candidate IMSFRs host probable stellar clusters and address the nature of their most massive stellar constituents.

341.09 – **A Spitzer View of the Giant Molecular Cloud Mon OB1/NGC 2264**

Valerie Rapson[1], J. L. Pipher[2], R. A. Gutermuth[3], S. T. Megeath[4], T. Allen[4]

[1]*Rochester Institute of Technology,* [2]*University of Rochester,* [3]*Smith College,* [4]*University of Toledo.*
9:00 AM - 6:30 PM

We present Spitzer mid-infrared and far-infrared images of the Mon OB1 giant molecular cloud, which contains the young star forming region NGC 2264 and several sub-clusters of young stellar objects (YSOs). With the Spitzer data, along with 2MASS photometry, we classify YSOs in the entire Mon OB1 giant molecular cloud (GMC) by their infrared-excess emission and study their distribution with respect to cloud material. We find that in regions with higher spatial YSO and molecular gas density there is a strong correlation between local surface density of YSOs and density of molecular gas as traced by dust. This correlation is roughly described as a power law in these quantities. We use a number counting technique to determine the fraction of cloud

members which are YSOs for different portions of the cloud that have differing average extinctions. We find that this disk fraction differs between the NGC 2264 region alone and the other regions of the Mon OB1 GMC. We compare these results with other molecular clouds and contrast our results for the NGC 2264 region with other estimates in the literature which use a different YSO classification approach.

341.10 – **New Herschel-identified Orion Protostars: Characterizing An Extreme Population Of Cold Sources**

Amelia Marie Stutz[1], T. Megeath[2], J. Tobin[3], W. Fischer[2], T. Stanke[4], B. Ali[5], J. Di Francesco[6], T. Henning[7], P. Manoj[8], D. Watson[8], HOPS team

[1]MPIA / University of Arizona/Steward Observatory, [2]University of Toledo, [3]NRAO, [4]ESO, Germany, [5]NHSC/IPAC/Caltech, [6]NRC-Canada, Canada, [7]MPIA, Germany, [8]University of Rochester.

9:00 AM - 6:30 PM

We present a new population of serendipitously identified Orion protostars. These protostars, designated PACS Bright Red Sources (PBRS), were identified in PACS 70 um observations for the Herschel Orion Protostar Survey (HOPS). Here we focus on the nine reddest PBRS in our sample: in contrast to the known Orion protostars targeted in HOPS, the reddest PBRS are undetected or very faint in the Spitzer 24 um imaging. They are redder than any of the known Orion Class 0 protostars, and appear similar in their 70 um to 24 um colors to the most extreme Class 0 objects known. These new Orion protostars are likely to be in a very early and short lived stage of protostellar evolution: the population of red PBRS is generally characterized by very low bolometric temperatures of ~ 25 K and bolometric luminosities of ranging from 1 to about 10 solar luminosities. Here we present our initial characterization of these sources through analysis of the observed Spitzer, Herschel, and APEX broad-band SEDs. In addition, we will present results from our observational campaign to obtain auxiliary long-wavelength data aimed at characterizing the PBRS.

341.11 – **Using The Herschel Hi-GAL Survey And The RMS Survey To Characterise Triggered Star Formation In Galactic Bubbles**

Charles C. Figura[1], L. K. Morgan[2], M. A. Thompson[3], J. S. Urquhart[4], T. J. T. Moore[2]

[1]Wartburg College, [2]Liverpool John Moores University (Astrophysical Research Institute), United Kingdom, [3]University of Hertfordshire, United Kingdom, [4]CSIRO Astronomy and Space Science, Australia.

9:00 AM - 6:30 PM

Galactic 'bubbles' have been shown by initial results from the Herschel Hi-GAL Survey and the Red MSX Source (RMS) Survey to be hosts to newly discovered populations of embedded young protostars.

We characterise the clump formation efficiency in several of these bubbles, and trace the indicators of triggering processes in the rims. The radial profiles of dust and gas column densities point to a 'shock-like' triggering process as a significant contributor to YSO formation. The large populations of protostars revealed by the surveys are sufficient to effectively rule out specific models of the triggering process as significant contributors to star formation in these bubbles.

341.12 – **Star Formation in Orion's L1630 Cloud: An Infrared and Multi-epoch X-Ray Study**

David Principe[1], J. H. Kastner[1], N. Grosso[2], K. Hamaguchi[3], M. Richmond[1], W. K. Teets[4], D. A. Weintraub[4]

[1]Rochester Institute of Technology, [2]Universite de Strasbourg, France, [3]Goddard Space Flight Center, [4]Vanderbilt University.

9:00 AM - 6:30 PM

We present a combined X-ray/IR study of L1630, a star-forming region in the Orion Molecular Cloud, with the goal of providing insight into the X-ray evolution of young stellar objects (YSOs). We have analyzed 11 Chandra X-Ray Observatory observations, obtained over the course of five years and totaling ~200 ks exposure time, targeting the eruptive YSO V1647 Ori in L1630. We used 2MASS and Spitzer data to identify and classify IR counterparts to L1630 X-ray sources that lie within ~12' of V1647 Ori. We identified a total of ~50 X-ray emitting YSOs with IR counterparts, including a handful of potential examples of X-ray-emitting Class 0/I objects. A subsample of ~20 X-ray-emitting YSOs were covered by all 11 Chandra observations targeting V1647 Ori; we present a detailed spectral/temporal analysis of this subsample, aimed at examining the evolution of X-ray spectral and temporal characteristics with YSO class.

341.13 – **Mid-infrared Imaging Of The W40 Star Forming Region Using Sofia-forcast**

Ralph Shuping[1], W. Vacca[2], T. Herter[3], J. Adams[3]

[1]Space Science Institute, [2]USRA-SOFIA, [3]Cornell Univ..

9:00 AM - 6:30 PM

We present mid-infrared images (5--40 micron) of the central portion of the W40 star forming region using the FORCAST instrument on SOFIA. These data were obtained as part of the SOFIA Basic Science Guest Investigator program during the summer of 2011, and are the highest resolution images of this region in the 20--40 micron wavelength range to date. Our images reveal a handful of protostellar sources in addition to diffuse emission from warm dust in the background nebula. We combine the SOFIA results with ground based photometry and spectroscopy to generate full optical/near-IR to mid-IR spectral energy distributions for the sources detected and compare them to standard models for young stellar objects of various masses and ages. We also discuss the nature of the mid-IR emission for IRS 3A, an early-B star that appears to be located within a small cocoon of warm dust.

341.14 – **KFPA Mapping of NH3 in the G111 Infrared Dark Cloud Filament**

Wayne M. Schlingman[1], Y. L. Shirley[2], G. Langston[3], A. Ginsburg[4]

[1]Center for Astronomy Education (CAE), Steward Observatory, Univ. of Arizona, [2]Steward Observatory, Univ. of Arizona; NRAO, [3]National Radio Astronomy Observatory, [4]University of Colorado.

9:00 AM - 6:30 PM

We present new K-band Focal Plane Array (KFPA) maps of ammonia in the G111 Infrared Dark Cloud near NGC 7538. We observe NH3 (1,1) and (2,2) inversion transitions simultaneously on each of the KFPA's seven pixels. We also present a temperature map of the filament from the ratio of these two lines. We also present H20 masers mapped with the KFPA. We directly compare the kinetic gas temperature with the dust temperature estimated from continuum observations. We also estimate the contribution from turbulence along the filament. We compare the properties of NH3 and H2O emission with evolutionary indicators for the G111 cores.

341.15 – **Investigating Star Formation at Low Metallicity with MIRI on JWST**

Margaret Meixner[1], J. Seale[1], M. Sewilo[2]

[1]STScI, [2]Johns Hopkins University.

9:00 AM - 6:30 PM

Most star formation in the universe occurs at low metallicity. Yet most star formation studies focus on nearby, high metallicity Galactic regions for which young stellar objects (YSOs) can be resolved and studied in detail. The nearby Large and Small Magellanic Clouds (LMC and SMC) offer a fantastic opportunity to investigate, on both large (galactic; kpc) and small (individual YSO; sub-parsec) scales, if and how the process of star formation changes with metallicity. The Mid-Infrared Instrument (MIRI) on JWST will be a powerful probe of this and other extragalactic star formation. In this poster, we present example programs that utilize the spectroscopic and photometric imaging capabilities of MIRI to investigate star formation in the Magellanic Clouds. These example programs build upon recently discovered YSOs in the LMC and SMC with the Spitzer-SAGE and Herschel-HERITAGE surveys. This work is support by NASA NAG5-12595.

341.16 – **Infrared Dark Clouds in the Cygnus-X Region**

Joseph L. Hora[1], T. Armstrong[2], K. Kraemer[3], T. Megeath[4], S. Carey[5], R. Gutermuth[6], H. A. Smith[1], E. Keto[1], G. G. Fazio[1], R. Simon[7], L. E. Allen[8], F. Motte[9], N. Schneider[9], S. Bontemps[10], J. D. Adams[11], D. Mizuno[3], S. Price[3], X. P. Koenig[12]

[1]Harvard-Smithsonian CFA, [2]University of Southampton, United Kingdom, [3]Boston College, [4]University of Toledo, [5]Spitzer Science Center, [6]Smith College, [7]University of Cologne, Germany, [8]NOAO, [9]CEA-Saclay, France, [10]Univ. of Bordeaux, France, [11]Cornell University, [12]NASA/GSFC.

9:00 AM - 6:30 PM

As part of the Cygnus-X Spitzer Legacy survey, we have begun a study of the infrared dark clouds (IRDCs) found in the IRAC and MIPS data of the region. Since most of the IRDCs are associated with the Cygnus-X complex at ~1.4 kpc, they are closer than most of those observed in the large Galactic surveys, and therefore we can better resolve their structure and detect the low-mass young stellar objects (YSOs) that have formed in association with the clouds. We present the results of our study, in which we have located and characterized the population of IRDCs. We have found the embedded YSOs and clusters associated with the clouds, including the 4.5 micron-bright extended sources that indicate outflows from YSOs. We show the distribution of IRDCs in the Cygnus-X complex and their relationship with the other well-known active sites of star formation.

341.17 – **An Analysis of Ultra-luminous X-ray Sources in Interacting Arp Galaxies**

Jacob A. Burleson[1], B. J. Smith[2], D. A. Swartz[3], O. Miller[1], M. A. Nowak[4], C. J. Struck[5]

[1]University of Alabama in Huntsville, [2]East Tennessee State University, [3]Universities Space Research Association NASA/MSFC, [4]MIT - CXC, [5]Iowa State

University.
9:00 AM - 6:30 PM

We have conducted a statistical analysis of the ultra-luminous X-ray point sources (ULXs) in all of the galaxies in the Arp Atlas of Peculiar Galaxies that have archival Chandra data and Sloan Digitized Sky Survey optical images. We find no excess of ULXs relative to the stellar mass in these peculiar galaxies; however, the subset of strongly interacting galaxies have a possible enhancement of a factor of ~3 in their number of ULXs per unit optical luminosity. Such an enhancement would be expected if ULX production is related to star formation, as interacting galaxies tend to have enhanced star formation rates on average. We find a possible enhancement in the number of ULXs in tidal features of the interacting galaxies compared to inner disks and to a sample of spiral galaxies. The Arp sample includes a few, relatively distant, LIRGs. We find a deficiency of ULXs per unit far-IR luminosity in these galaxies. In these systems, AGNs may contribute to powering the far-infrared at the expense of star formation; alternatively, ULXs may be highly obscured in the X-ray in these galaxies and therefore not detected by these Chandra observations which suffer from incompleteness in these distant galaxies. Finally, we compare the ULX luminosity function to that of normal spiral galaxies.

acknowledgement:

This research was supported by Chandra Award Numbers AR9-0010A, GO9-0098X, and GO0-11099A issued by the Chandra X-ray Observatory Center.

341.18 – **The Free-fall Time of Finite Sheets and Filaments**

Enrique Vazquez-Semadeni[1], J. A. Toala[1], G. C. Gomez[1]

[1]*CRYA-UNAM, Mexico.*
9:00 AM - 6:30 PM

Molecular clouds often exhibit filamentary or sheet-like shapes. We compute the free-fall time ($\tff$) for finite, uniform, self-gravitating circular sheets and filamentary clouds of small but finite thickness, so that their volume density ρ can still be defined. We find that, for thin sheets, the free-fall time is larger than that of a uniform sphere with the same volume density by a factor proportional to $\sqrt{A}$, where the aspect ratio *A* is given by *A=R/h*, *R* being the sheet's radius and *h* is its thickness. For filamentary clouds, the aspect ratio is defined as *A=L/\calR*, where *L* is the filament's half length and $\calR$ is its (small) radius, and the modification factor is a more complicated, although in the limit of large *A* it again reduces to nearly $\sqrt{A}$. We propose that our result for filamentary shapes naturally explains the ubiquitous configuration of clumps fed by filaments observed in the densest structures of molecular clouds. Also, the longer free-fall times for non-spherical geometries in general may contribute towards partially alleviating the ``star-formation conundrum'', namely, that the star formation rate in the Galaxy appears to be proceeding in a timescale much larger than the total molecular mass in the Galaxy divided by its typical free-fall time. If molecular clouds are in general formed by thin sheets and long filaments, then their relevant free-fall time may have been systematically underestimated, possibly by factors of up to one order of magnitude.

342 – Cosmology and Galaxy Formation From SDSS-III/BOSS

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

342.01 – **The First Large Scale Galaxy Clustering Measurements from the Baryon Oscillation Spectroscopic Survey (BOSS)**

David J. Schlegel[1], SDSS-III collaboration

[1]*LBNL.*
9:00 AM - 6:30 PM

Measurements of galaxy clustering are presented from the Baryon Oscillation Spectroscopic Survey (BOSS), using the Data Release 9 (DR9). This sample contains approximately 275,000 massive galaxies, out to redshift 0.7 covering 3,200 square degrees. This BOSS DR9 sample represents the largest sample of the Universe ever surveyed at this density, which is sufficient to ensure that our measurements are cosmic variance limited. We present multipoles of the correlation function and the spherically averaged power spectrum measured from these data. The acoustic features are detected at high significance, a clear indication that the evolution of the Universe on large-scales follows standard linear theory.

342.02 – **A 2% Bao Distance Measurement From Density-field Reconstruction In The Sdss**

Xiaoying Xu[1], A. Cuesta[2], D. Eisenstein[3], K. Mehta[1], N. Padmanabhan[2]

[1]*University of Arizona,* [2]*Yale University,* [3]*Harvard University.*
9:00 AM - 6:30 PM

We present the first application of density-field reconstruction to the Baryon Acoustic Oscillations (BAO) signal using the luminous red galaxy sample in the seventh data release of the Sloan Digital Sky Survey. Reconstruction was developed to reduce the uncertainties on the measured BAO scale. We also introduce a new method for estimating a smooth covariance matrix and perform detailed tests to verify the robustness of our fitting model. We find that the error on the acoustic scale improves from 3.4% before reconstruction to 1.9% after reconstruction at z=0.35, a decrease equivalent to tripling the survey volume. This marks the most accurate and robust measurement of the z=0.35 acoustic scale to date.

342.03 – **New Results from a Census of Metal Absorption Lines in the BOSS DR9 Quasar Spectra**

Britt Lundgren[1], D. G. York[2], Y. AlSayyad[3], A. Myers[4], P. Petitjean[5], M. Pieri[6], N. Ross[7], S. Vikas[8], M. Wood-Vasey[8]

[1]*Yale University,* [2]*Enrico Fermi Institute, University of Chicago,* [3]*University of Washington,* [4]*University of Wyoming,* [5]*Institut d'Astrophysique de Paris, France,* [6]*Institute of Cosmology & Gravitation, University of Portsmouth, United Kingdom,* [7]*Lawrence Berkeley National Laboratory,* [8]*University of Pittsburgh.*
9:00 AM - 6:30 PM

Foreground absorption features observed in the spectra of distant quasars provide insight into the evolution of elemental abundances in galaxies and the intergalactic medium as well as the growth of large-scale structure from high redshift to the present. Through the development of an automated pipeline to extract and identify absorption lines in SDSS-III BOSS quasar spectra, we have compiled the largest sample of metal absorbers to date. Using these data, we present new high-precision measurements of the redshift evolution of the number densities and equivalent width distributions of Mg II and C IV absorbers. These measurements sample a wider redshift range than previously attainable and provide new insights into the evolution of the gas content of galaxy haloes from z~5.

342.04 – **Cosmological Constraints from the Angular Power Spectra of SDSS DR8 Photometric LRGs**

Antonio Jose Cuesta-Vazquez[1], S. Ho[2], H. Seo[3], M. White[4], A. J. Ross[5], S. Saito[4], B. A. Reid[3], N. Padmanabhan[1], W. J. Percival[5], R. de Putter[6], D. J. Schlegel[3], D. J. Eisenstein[7], F. Prada[8], L. A. N. da Costa[9], F. de Simoni[9], R. A. Skibba[10], L. Verde[6], M. Viel[11]

[1]*Yale University,* [2]*Carnegie Mellon University,* [3]*Lawrence Berkeley National Laboratory,* [4]*University of California at Berkeley,* [5]*Institute of Cosmology and Gravitation, University of Portsmouth, United Kingdom,* [6]*Institute of Cosmos Sciences, University of Barcelona, Spain,* [7]*Center for Astrophysics, Harvard University,* [8]*Instituto de Astrofisica de Andalucia, Spain,* [9]*Observatorio Nacional, Brazil,* [10]*Steward Observatory, University of Arizona,* [11]*Osservatorio Astronomico di Trieste, Italy.*
9:00 AM - 6:30 PM

We derive cosmological constraints from the full shape of the angular power spectra of luminous red galaxies from the SDSS III DR8 imaging catalog. Our sample comprises an unprecedented dataset of almost one million galaxies over 10,000 deg^2 in the redshift range 0.45<z<0.65. Accurate redshift distributions are derived from a large number of spectroscopic redshifts measured by the SDSS III BOSS survey, largely reducing the uncertainties in the use of the imaging data for clustering analyses. We use this redshift distribution information to generate theory angular power spectra for different cosmologies and we compare them to the angular power spectra from the data, which is computed using an optimal quadratic estimator method. An adequate treatment of stellar contamination and systematics in the imaging data further reduces any possible bias in our results. We combine this dataset with CMB data from WMAP7 to find the best-fit cosmology using the known Markov-Chain MonteCarlo code CosmoMC. We test our fitting method against mock galaxy catalogs from cosmological simulations with known cosmology to show the robustness of our constraints. We discuss on the constraining power of this dataset to estimate cosmological parameters, and conclude that the imaging data by itself is able to cast encouraging results preceding the high quality spectroscopic measurement of the clustering of luminous red galaxies from BOSS.

343 – Dust

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

343.01 – **Differential Depletion of Mg and Fe in Planetary Nebulae: Implications for the Composition of AGB-Star Dust**

Harriet L. Dinerstein[1], F. Prasla[1], A. K. Speck[2]

[1]*Univ. of Texas, Austin,* [2]*Univ. of Missouri.*
9:00 AM - 6:30 PM

We have investigated the gas-phase abundances of Mg and Fe, both refractory elements that are potentially major constituents of silicates and other minerals, for 25 planetary nebulae. The Mg abundances are derived from Mg II 4481 A, a recombination line of Mg++; we obtain Fe/H from [Fe III] 4658 A, after correcting for ionization structure. We find strikingly different behavior for the two elements. Fe is deficient by factors of 20-200 relative to solar, presumably due to incorporation into dust that condensed while the star was on the Asymptotic Giant Branch (AGB). On the other hand, Mg/H is virtually solar, implying that Mg is at most minimally depleted. This result is surprising since some of the nebulae display mid-infrared emission features often attributed to forsterite, the pure-Mg form of crystalline olivine. If this identification is correct, there must be only a small mass of Mg-rich crystalline silicate dust, coexisting with a larger amount of Fe-rich amorphous silicates or another Fe-bearing material. Another possibility is that the observed features might actually arise from Fe-rich crystalline silicates such as fayalite, which provide a good fit to the spectra of some AGB stars (Pitman et al. 2010, MNRAS, 406, 460; Guha Nigoya et al. 2011, ApJ, 733, 93). Finally, our Mg abundances are based on an optical recombination line (ORL), and such lines from C, N, O, Ne tend to be anomalously strong in nebulae. Although empirically Mg does not correlate with the ORL abundance discrepancy (Barlow et al. 2003, ASPC, 209, 273; Wang & Liu 2007, MNRAS, 381, 669), solving the origin of the ORL effect would increase our confidence in our Mg/H values. This work was supported by NSF grants AST-0708245 to HLD and CAREER AST-0642991 to AKS, and Big XII Faculty Fellowships to both.

343.02 – **Spitzer Sage/lmc Observations Of Extreme Carbon Stars As A Probe Of Carbon-rich Stardust Properties**

Nicholas Parmley[1], A. K. Speck[1], A. J. Mulia[1], SAGE-Spec team

[1]*University of Missouri.*
9:00 AM - 6:30 PM

Intermediate mass stars eventually evolve into asymptotic giant branch (AGB) stars and are major contributors of new mateiral to the interstellar medium (ISM) and the next generation of stars. The Spitzer legacy program Surveying the Agents of Galaxy Evolution (SAGE) performed an infrared survey of the Large and Small Magellanic Clouds(LMC and SMC, respectively). SAGE's goal is to follow the life cycle of matter that drives galactic evolution. SAGE-Spec is the spectroscopic follow up project in which we study the dust production in more detail. Here we present a study of extreme carbon stars in the LMC. These stars have intermediate mass and are losing copious amounts of material to the ISM. These carbon stars have such high mass-loss rates that the dust shells they form completely obscure their starlight. The SAGE program has discovered that these extreme carbon stars are more common than expected compared to the number found in our own galaxy and for the sub-solar metallicity of the LMC. This dataset allows us to investigate the variations in properties of the dust around are fairly homogeneous sample of stars. We show that the emissivity of the dust around extreme carbon stars varies markedly and is rarely consistent with the commonly-assumed emissivity power-law value of 1.2.

343.03 – **The Enigmatic 13 micron Feature in the Spectra of AGB Stars.**

Nelson De Souza[1], A. K. Speck[1]

[1]*University of Missouri.*
9:00 AM - 6:30 PM

Understanding the nature and formation of cosmic dust is crucial to understanding the Universe. Evolved intermediate mass stars (i.e. AGB stars) are major contributors of dust to the cosmos. Dust around AGB stars are studied by means of infrared spectroscopy from which we observe several interesting spectral features. The observed AGB star spectra have been classified according to their shapes and wavelength positions of the dust features. Alongside the main spectral features around 8-12 microns, there is an enigmatic 13 micron feature that appears in about half the oxygen-rich AGB stars. The carrier of this feature has not yet been unequivocally identified but has been attributed to various dust species, including corundum (crystalline Al2O3), spinel (MgAl2O4), and silica (SiO2). While there have been several attempts to determine the cause of this 13 micron feature, previous studies have been somewhat contradictory. Here we present data and parameters for a large sample of oxygen-rich AGB stars and determine whether the strength of the 13 micron feature is correlated with any of these stellar parameters such as mass-loss rate, proper motion, radial velocity, and period.

343.04 – **Modeling the Effect of Pulsation on the Dust Spectrum of Carbon Star V Cyg.**

Angela Speck[1], B. Hester[1], A. Corman[1], K. Volk[2], G. C. Sloan[3]

[1]*Univ. of Missouri,* [2]*Space Telescope Institute,* [3]*Cornell University.*
9:00 AM - 6:30 PM

Intermediate mass stars are major contributors of material to interstellar medium via mass loss during their Asymptotic Giant Branch (AGB) phase. The mass loss is believed to be driven by the pulsation of these stars, but the precise effects of stellar pulsations on dust formation and mass loss remain a mystery. Here we present DUSTY radiative transfer models of a single carbon star V Cyg, whose infrared spectrum was observed using ISO SWS six times over the course of a single pulsation cycle. We find that the spectrum changes very little from maximum to minimum light and the consequent changes in the dust shell parameters are small. The model fits to the observed spectra are consistent with no changes in the type dust formed and only small changes in the dust condensation temperature and/or the optical depth.

343.05 – **Dust Destruction By The Reverse Shock In The Cassiopeia A Supernova Remnant**

Elisabetta Micelotta[1], E. Dwek[2]

[1]*University of Western Ontario, Canada,* [2]*NASA Goddard Space Flight Center.*
9:00 AM - 6:30 PM

It has been demonstrated by observations that young supernovae (SNe) are indeed able to efficiently synthesize dust. However, the total dust mass estimated from observations is still orders of magnitude lower than the amount of dust predicted by models. At the same time, SNe represent the major agent responsible for dust destruction. Because SNe are possibly the only viable dust factory in the early Universe, it is extremely important to establish the origin of this discrepancy. It could be that the models of dust coagulation in supernova ejecta need to be corrected, or that the dust is present but undetectable, due to environmental conditions or technical limitations. It is also possible that a significant fraction of the newly formed dust is destroyed within the supernova remnant. Our work explores this latter option.

In the Cassiopeia A supernova remnant, dust emission has been observed associated with the optical knots containing recently formed material. The dust present in the clumps is threatened by the reverse shock traveling through the ejecta toward the center of the supernova. The shock is able to disrupt the clumps and will inject the dust grains into a hot gas, where they will be eroded and possibly destroyed by thermal and inertial sputtering. We present a model that describes the propagation of the reverse shock into the supernova cavity and evaluates the destruction of the newly formed dust, taking into account the variation of the physical properties of both the shock and the ejecta across the remnant.

343.06 – **Dust Distribution and Properties in the Orion-Eridanus Superbubble Region**

Young-soo Jo[1], K. Min[1], T. Lim[1], K. Seon[2]

[1]*KAIST, Korea, Republic of,* [2]*KASI, Korea, Republic of.*
9:00 AM - 6:30 PM

We have derived not only the albedo and scattering asymmetry factor $g \equiv \langle\cos\theta\rangle$ of the interstellar dust grains at 1565 Å but also the 3D distribution of dust clouds using FIMS/SPEAR observations of diffuse radiation in Orion Eridanus Superbubble region. Initial dust distribution for simulation was set by referring SFD dust extinction map and J.-L. Vergely's 3D dust extinction distribution map. The dust clouds were roughly divided into 5 different regions according to the $E(B-V)$ value, distance and thickness. After we found the best values of albedo and g under the initial dust distribution, then we tried to find the best fit for the 3D dust distributions under the former albedo and g. This process was iterated until the (albedo, g) converges certain values with the corresponding 3D distribution of dust clouds. Finally, dust properties and 3D distribution derived by this process can give us further reliable information for the Orion Eridanus Superbubble region.

343.07 – **Dust-scattered FUV halo around Spica**

Choi Yeon-Ju[1], J. Park[2], T. Lim[1], K. Seon[3], K. Min[1]

[1]*KAIST, Korea, Republic of,* [2]*KOREAN INTELLECTUAL PROPERTY OFFICE, Korea, Republic of,* [3]*KASI, Korea, Republic of.*
9:00 AM - 6:30 PM

The far ultraviolet (FUV) wavelength (900~1750Å) range includes a wealth of important astrophysical information related to the cooling of hot gas, fluorescent emission from H_2 molecules, and star light scattered off dust particles. Among these, we would like to focus on the scattered emission of the central star by dust with the example of the FUV halo surrounding α Vir (Spica). While scattering properties of dust have been studied with the GALEX data, the improved dataset of STSAT-1 revealed many detailed structures of this interesting region. For example, the FUV continuum map obtained from the STSAT-1 observations shows enhanced emission in the southern part of the Spica halo region, where the dust level is also high. In fact, the FUV continuum intensity is seen to have a good correlation with the IRAS 100 μm emission data. It is also seen that the scattered spectrum is softer than the original one emitted by the central star, which is attributed to the increase in the dust-scattering albedo with wavelength. We have developed a Monte Carlo code that simulates dust scattering of light including multiple encounters. The code is applied to the present Spica halo region

to obtain the scattering properties such as the albedo and the phase function asymmetry factor.

343.08 – **A FUV Study in Taurus-Auriga-Perseus(TAP) Complex**

Lim Tae-Ho[1], K. Min[1], K. Seon[1]

[1]*KAIST, Korea, Republic of.*

9:00 AM - 6:30 PM

We present Far-UV continuum map of the Taurus-Auriga-Perseus(TPA) complex, one of the largest local associations of dark cloud located in (l, b)=([152,180], [-28, 0]), using both FIMS/SPEAR and GALEX. We also present the result of FUV dust scattering simulation in the same region, which is based on Monte Carlo Radiative Transfer(MCRT) technique. We basically assume that scattered starlight is the most prominent component of FUV continuum in this region. From the assumption we compare our scattering simulation results to FIMS-GALEX unified FUV continuum and then through that we prove the spatial distribution of the complex region. The simulation results reveal as well their own scattering properties such as albedo(a) and asymmetry factor(g) in the whole TAP region at 1565A. We compare the results above to some previous studies related to this region including effective distance of dark clouds, dust density and dust distribution.

343.09 – **Light echoes from the Supernova Factory NGC 6946**

Ben Sugerman[1], SEEDS Collaboration

[1]*Goucher College.*

9:00 AM - 6:30 PM

NGC 6946 has had 9 supernovae discovered in the last century, making it the most prolific supernova factory in the nearby universe. We report on our ongoing study of many of these objects as part of the SEEDS (Survey for Evoution for Emission from Dust in Supernovae) collaboration, reporting the discovery and analysis of pre-existing and newly-formed dust through thermal emission and light echoes.

343.10 – **Exploring the Origin of Dust in the Solar Neighborhood**

Adria C. Updike[1], E. Dwek[2]

[1]*Dickinson College,* [2]*NASA/GSFC.*

9:00 AM - 6:30 PM

Several papers have pointed out a discrepancy between the current rates of dust production by stellar sources and the observed amount of dust in the solar neighborhood. We investigate the possibility that a peak in a variable star formation history could have led to a higher amount of dust today through delayed injection. We employ a cyclic star formation history for the last 3 Gyr based on Hipparcos data to recalculate the contribution of stellar dust in the ISM using the most up-to-date models of stellar return rates. We find that although the varying star formation history will lead to peaks in the amount of observed dust, it cannot explain the high quantity of dust observed in the solar neighborhood today. Therefore, most of the dust in the ISM today must have been formed from preexisting stellar condensates.

343.11 – **Understanding Stardust via Spatially-Resolved Spectroscopy: A Case Study on R Hya**

Aaron Kaberline[1], S. Guha Niyogi[1], A. K. Speck[1], K. Volk[2]

[1]*University of Missouri,* [2]*Space Telescope Science Institute.*

9:00 AM - 6:30 PM

Cosmic dust strongly affects many astrophysical environments and is therefore crucial to our understanding of the Universe in general. For that purpose, we study the stardust that forms around stars as they die and return their material (including newly formed elements) to interstellar space. Recent studies have produced results that contradict the conventional models for dust formation, postulating that dust around optically thin oxygen-rich intermediate mass evolved stars (asymptotic giant branch [AGB] stars) is comprised of crystalline rather than amorphous silicates. We present an analysis of Gemini/Michelle near infrared (IR) observational data of the O-rich low-mass loss rate AGB star R Hya as a case study. With spatially-resolved spectroscopy we investigate changes in features of IR spectra, diagnostic of the incident material, with respect to position around the central star. We present the spatial distributions among three prominent spectral features of R Hya at 9, 10, and 11 microns, as well as how the shapes and peak positions of broad spectral features change with spatial position. Spatially-resolved dust spectra allow us to determine which features are correlated and help us determine the true dust carrier(s) of the observed features. Furthermore, changes in the spectrum with respect to position in the circumstellar shell allow us to test dust formation hypotheses. We analyze how the spectral features and slope of the dust continuum change, using flux ratios of the three features of interest and pseudo-continuum points at 8 and 12 microns to compare the relative magnitudes of each feature in each spectrum.

343.12 – **UV-to-IR Spectral Energy Distribution Fitting with DIRTY - Initial Results**

Ka Hei Law[1], K. D. Gordon[2]

[1]*Johns Hopkins University,* [2]*Space Telescope Science Institute.*

9:00 AM - 6:30 PM

We study dust and star formation in nearby galaxies by fitting the observed ultraviolet (UV) to infrared (IR) spectral energy distributions (SEDs) of regions of galaxies and entire galaxies using DIRTY - a 3D Monte Carlo dust radiative transfer model - and stellar evolutionary synthesis models. To our knowledge, this is the first systematic multi-wavelength study with a physically based radiative transfer model focused on dust and stars in galaxies. Due to the computational complexity of the problem, previous studies were not physically based. With various optimizations in our model and the availability of large computer clusters such as the TeraGrid, it has now become feasible. It is important to model both UV and IR simultaneously and self-consistently. Dust absorbs radiation strongly in the UV and re-emits the energy as a modified blackbody in the IR. Fitting UV and optical alone gives significant degeneracy between the stellar age and the amount of dust present, while fitting IR alone tells us very little about the underlying stellar populations. It is common to constrain observations using the UV and the total IR, but with the IR spectrum instead of the integrated IR we gain extra information such as dust temperature. Our model grid allows us to physically connect the stars and the dust and look at the full problem with the whole possible range of galaxies from dwarf galaxies to ultra-luminous galaxies.

343.13 – **The Effect Of Metallicity And C/O On The Low-Contrast Dust Features Of Low-Mass-Loss Rate O-Rich AGB Stars.**

David J. Arrant[1], A. K. Speck[1], S. J. Chan[1]

[1]*University of Missouri.*

9:00 AM - 6:30 PM

Asymptotic Giant Branch (AGB) stars are major contributors of material to the interstellar medium. The chemistry of the dust ejected into the ISM is dictated by the ratio of carbon to oxygen atoms. The reason for this division is that carbon monoxide (CO) is very stable, so the most of the carbon and oxygen will be trapped in CO. The excess of the more abundant element, carbon or oxygen, will dominate the dust formation. Consequently AGB stars either are O-rich or carbon-rich (C-rich). Carbon, and possibly some oxygen atoms are made and dredged up to the stellar surface during the AGB phase, and therefore an AGB star has timing varying C/O, starting out with values expected to be close to solar. It has been suggested that even small changes in C/O may affect the precise composition and structure of the O-rich dust forming around these stars. Moreover, metallicity affects the atoms available for dust formation.

The infrared spectra of oxygen-rich (O-rich) asymptotic giant branch (AGB) stars show a broad 9-13 micron feature. Here we present a study of the effect of both C/O and the metallicity on low-intensity broad dust features around O-rich AGB stars, we find that while dust feature parameters do not correlate with C/O, they do correlate with the Fe-group abundances. The implications of this finding are discussed.

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344 – Circumstellar Disks

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

344.01 – **Reconstruction of Lyman Alpha Radiation in Classical T-Tauri Stars**

Eric Schindhelm[1], K. France[1]

[1]*Univ. of Colorado.*

9:00 AM - 6:30 PM

Lyman alpha emission dominates the UV radiation field in the inner regions of protoplanetary disks, driving the heating and destruction of dust as well as gas chemistry. However, in most of these disks our knowledge of the Lyman alpha profiles is extremely limited due to circumstellar and interstellar extinction. We have used Lyman alpha-fluoresced H2 emission in HST-COS spectra to reconstruct the Lyman alpha profiles for a sample of ~30 classical T-Tauri stars. The observed fluxes of 7 fluorescent progressions are compared with model Lyman alpha profiles to determine the incident radiation field. We compare these Lyman alpha profiles with those responsible for CO photo-excitation in these targets to constrain the spatial distribution of molecules in inner disk atmospheres.

344.02 – **The Gravo-Magneto Limit Cycle in Accretion Disks**

Rebecca G. Martin[1], S. H. Lubow[1]

[1]*STScI.*

9:00 AM - 6:30 PM

Previous theoretical studies have found that repeating outbursts can occur in certain regions of an accretion disk, due to sudden transitions in time from gravitationally produced turbulence to magnetically produced turbulence. We analyze the disk evolution in a state diagram that plots the mass accretion rate versus disk surface density. We determine steady state accretion branches that involve gravitational and magnetic

sources of turbulence. Using time-dependent numerical disk simulations, we show that cases having outbursts track along a nonsteady 'dead zone' branch and some steady state accretion branches. The outburst is the result of a rapid inter-branch transition. The gravo-magneto outbursts are then explained on this diagram as a limit cycle that is analogous to the well-known S-curve that has been applied to dwarf nova outbursts. The diagram and limit cycle provide a conceptual framework for understanding the nature of the outbursts that may occur in accretion disks of all scales, from circumplanetary to protoplanetary to AGN accretion disks.

344.03 – **Near-IR Spectral Variability Of Young Stars: A Multi-year Survey**

Clint Hawkins[1], J. Eisner[2], A. L. Rudolph[1]

[1]*Department of Physics and Astronomy, California State Polytechnic University, Pomona,* [2]*Department of Astronomy and Steward Observatory, University of Arizona.*

9:00 AM - 6:30 PM

T-Tauri type stars exhibit variability across the electromagnetic spectrum, including in the visible and the infrared regions. While spectroscopic variability in the optical range has been previously investigated, variability in the near-IR has not been explored as thoroughly. We have been tracking the spectral variability of about 40 young stars in the near-IR during the past year. Using the 90-inch Bok telescope on Kitt Peak, we observed our sample with FSPEC during four five-night runs, two in 2010 separated by one month and two in 2011, also separated by one month. Here we present spectra for each of these epochs that show emission from the Brackett Gamma (BrG) transition of hydrogen. Changes in the BrG line profile from epoch to epoch are used to constrain the properties of accretion onto our young star targets as a function of time. We acknowledge the NSF for funding under Award No. AST-0847170, a PAARE Grant for the Calfornia-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE).

344.04 – **The Elusive SR-21 Inner Cavity: Polarized Images Reveal that Submillimeter-Resolved Cavity is Not Present in the NIR**

Katherine B. Follette[1], M. Tamura[2], J. Hashimoto[2], SEEDS Team

[1]*University of Arizona,* [2]*National Astronomical Observatory of Japan, Japan.*

9:00 AM - 6:30 PM

We present Subaru HiCIAO Polarized Differential Imaging (PDI) data of the SR-21 transitional disk at H band. Computed polarization vectors show centrosymmetric geometry in the region surrounding the star and are consistent with an extended scattered light disk . Although previous studies have revealed a cleared inner cavity inside of 18AU, our results show no evidence of a cavity at shorter wavelengths. This has interesting theoretical implications, as it would appear that the cavity resolved at submillimeter wavelengths contains enough small grains to scatter strongly at H-band.

344.05 – **Resolving Protoplanetary Disks at Millimeter Wavelengths**

Woojin Kwon[1], L. W. Looney[1], L. G. Mundy[2], W. J. Welch[3]

[1]*University of Illinois at Urbana-Champaign,* [2]*University of Maryland,* [3]*University of California at Berkeley.*

9:00 AM - 6:30 PM

The physical properties of protoplanetary disks, which harbor the initial conditions of planet formation, are mainly studied by interferometers at millimeter/submillimeter wavelengths tracing dust thermal emission. We have observed six protoplanetary disks at 1.3 and 2.7 mm continua using the Combined Array for Research in Millimeter-wave Astronomy with an excellent image fidelity and angular resolution up to 0.13 arcsecond. Through visibility modeling in Bayesian inference, we have constrained the physical properties such as density distributions, dust properties, masses, sizes, etc. based on two disk models: power-law disk and viscous accretion disk models. In addition, we compare the two disk models quantitatively. As a progress from the previous work (Kwon's dissertation), we have applied more realistic data uncertainties and temperature distributions for the modeling, as well as added more data at high angular resolution.

344.06 – **SEEDS Polarimetric Differential Imaging of LkCa 15**

John P. Wisniewski[1], M. Fukagawa[2], M. Goto[3], C. Grady[4], J. Hashimoto[5], T. Henning[6], K. Hodapp[7], M. Honda[8], M. Janson[9], T. Kudo[5], C. Thalmann[10], B. Whitney[11], M. Tamura[5], SEEDS Team

[1]*University of Washington,* [2]*Osaka University, Japan,* [3]*MPIA, Germany,* [4]*NASA GSFC & Eureka Scientific,* [5]*NAOJ, Japan,* [6]*MPIA,* [7]*University of Hawaii,* [8]*Kanagawa University, Japan,* [9]*Princeton University,* [10]*Anton Pannekoek Institute, Netherlands,* [11]*University of Wisconsin.*

9:00 AM - 6:30 PM

LkCa 15 is young (3-5 Myr), solar-like, classical T Tauri system which is classified as a pre-transitional disk system from analysis of its IR SED (Espaillat et al 2007). Recent near-IR imagery of LkCa 15, obtained with the HiCIAO instrument as part of the Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) program, provided the first scattered light detection of the gap in the LkCa 15 disk (Thalmann et al 2010). We present a detailed analysis of H-band polarimetric differential imagery (PDI) of LkCa 15 obtained as part of the SEEDS program, along with Monte Carlo radiative transfer simulations of the system.

We acknowledge funding from NSF AST 1009314 and AST 1008440.

344.07 – **On The Nature Of The Transition Disk Around Lkca 15**

Andrea Isella[1], L. M. Perez[1], J. M. Carpenter[1]

[1]*CALTECH.*

9:00 AM - 6:30 PM

CARMA 1.3 mm continuum observations resolve the LkCa 15 circumstellar disk on a spatial scale of 25 AU and reveal a large inner gap in the dust emission. By comparing the observations with theoretical disk models, we calculate that the dust emission arises from an azimuthally symmetric ring that extends between 40-120 AU. The continuum cavity is consistent with either a sharp drop of the 1.3 mm dust optical depth at 42.5 AU or a smooth inward decrease between 3-85 AU. We argue that distinguishing between these two scenarios is a crucial step to understand the nature of dust continuum cavity, and of transition disks in general. We show that our forthcoming Band 9 Cycle 0 ALMA observations will be able to disentangle these two scenarios with high significance. These observations will ultimately enable us to understand whether the cavities observed in transition disks are formed by the presence of Jupiter size planets or by other physical processes.

344.08 – **The Nature of Transition Circumstellar Disks in Perseus, Taurus, and Auriga**

Lucas A. Cieza[1], M. Schreiber[2], G. Romero[2], J. P. Williams[1], A. Rebassa-Mansergas[2]

[1]*University of Hawaii,* [2]*Universidad de Valparaiso, Chile.*

9:00 AM - 6:30 PM

As part of an ongoing program aiming to characterize a large number of Spitzer-selected transition disks (disks with reduced levels of near-IR and/or mid-IR excess emission), we have obtained millimeter wavelength photometry, high-resolution optical spectroscopy, and adaptive optics near-infrared imaging for a sample of 31 transition objects located in the Perseus, Taurus, and Auriga molecular clouds. We use these ground-based data to estimate disk masses, multiplicity, and accretion rates in order to investigate the mechanisms potentially responsible for their inner holes. Following our previous studies in the Ophiuchus, Lupus, Corona Australis and Scorpius regions, we combine disk masses, accretion

rates and multiplicity data with other information, such as SED morphology and fractional disk luminosity to classify the disks as strong candidates for the following categories: grain-growth dominates disks (7 objects), giant planet forming disks (6 objects), photoevaporating disks (7 objects), debris disks (11 objects), and cicumbinary disks (1 object, which was also classified as a photoeavaporating disk). Combining our sample of 31 transition disks with those from our previous studies results in a sample of 74 transition objects that have been selected, characterized, and classified in an homogenous way. We discuss this combined high-quality sample in the context of the current paradigm of the evolution and dissipation of protoplanetary disks and use its properties to constrain different aspects of the key processes driving their evolution.

344.09 – **On the Chemistry of Circumstellar Disk Around MWC349A**

Kristen Lagergren[1], A. Bans[2], V. Strelnitski[3]

[1]*University of Virginia & Maria Mitchell Observatory,* [2]*University of Chicago & Maria Mitchell Observatory,* [3]*Maria Mitchell Observatory.*

9:00 AM - 6:30 PM

The evolutionary status of MWC 349A - the unique source of hydrogen maser and laser radiation arising in a massive circumstellar disk - is still a matter of debate. One way to shed light on this issue would be to measure the isotopic composition of the disk. We performed computer simulations of the chemical composition of the disk using the package CLOUDY (Ferland et al. 1998). The best agreement between the calculated hydrogen line strength ratios and those measured by Hamann and Simon (1986) was achieved for a model with a central (black body) star of T ≈ 20,000 K and a disk with the inner radius ~ 10^{14} cm, hydrogen density at the inner radius ~10^{8} cm^{-3} and the r^{-2} drop of density with radius. We present the column densities predicted by CLOUDY for observed (CO) and several not yet observed molecules containing the major isotopes of C, N, O and discuss the prospects of detecting and measuring the radio lines of these molecules and their isotopologues with existing and forthcoming facilities. This project was supported by NSF/REU grant AST-0851892, the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring, and the Nantucket Maria Mitchell Association.

344.10 – **Observing Compact Disks Inside Pre-Planetary Nebulae with the Very Large Telescope Interferometer**

Stacey N. Bright[1], O. De Marco[1], O. Chesneau[2], E. Lagadec[3], H. Van Winckel[4], B.

J. Hrivnak[5]

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9:00 AM - 6:30 PM

Asymptotic giant branch (AGB) stars appear to lose mass spherically, but many planetary nebulae (PNe) resulting from the spherical AGB mass-loss have non-spherical morphologies. It is likely that the mechanism that causes the heavy AGB mass loss is related to the mechanism that dictates the ejecta's departure from sphericity. Disks are known to exist around evolved, mass-losing AGB and post-AGB stars and are suspected to play a fundamental role in the shapes of PNe. Theoretical work envisions their role as the collimating agent resulting in non-spherical mass-loss.

Compact disks have been found in some bipolar PNe, but their role in the shaping process remains unknown. Compact Keplerian disks are found to be common around post-AGB binaries; however, these objects may never develop into PNe as no nebulae are observed. Collimated nebulae shining by reflected light or shock ionisation surround another group of post-AGB stars, known as pre-PNe. Pre-PNe are thought to be the immediate precursors to non-spherical PNe.

We have begun the first systematic survey of pre-PNe, with the Very Large Telescope Interferometer (VLTI). We seek to detect disks left behind by the shaping process and compare these disks to those around other post-AGB stars and PNe. At present, three out of four pre-PNe observed have shown evidence of disks in their inner-circumstellar regions. One of them, IRAS 16279-4757 shows evidence for a disk similar to those seen in young PNe in addition to a smaller disk inside this disk. Observations were also carried out for IRAS 17347-3139 and IRAS 17150-3224. The initial results show evidence of a compact source in the centre of these targets as well. We are conducting detailed radiative transfer models to derive disk parameters such as inner and outer radii, scale-height, mass, and inclination. Future observations of more pre-PNe are still to come.

344.11 – **Properties of the Inner H2 Disks of Protoplanetary Systems**

Kevin France[1], E. Schindhelm[1], G. Herczeg[2]

[1]*CASA / Colorado,* [2]*KIAA / Peking University, China.*

9:00 AM - 6:30 PM

We present a sample of 33 young (age < 12 Myr) circumstellar disk systems observed with the HST-Cosmic Origins Spectrograph. Tens to hundreds of photo-excited H2 emission lines are detected in every gas-rich classical and transitional disk. Total fluxes and velocity profiles are measured for several LyA-pumped H2 progressions in each target. The emission lines are spectrally resolved, arguing that the emitting gas is in a rotating disk at an orbital distance of less than ~5 AU. We observe a decline in the amount of H2 present in the inner disk as a function of system age, however gas-rich inner disks with ages between 5 - 10 Myr are observed. Many of these sources show strong evidence for dust clearing, suggesting that the survival of remnant H2 gas in the inner 5 AU of protoplanetary systems is common.

344.12 – **Circumstellar Gas-disk Variability And Exo-comet Detection In The Debris Disks Of A-type Stars**

Sharon Lynn Montgomery[1], B. Y. Welsh[2], R. A. Cooper[1]

[1]*Clarion University,* [2]*U.C. at Berkeley, Space Science Laboratory.*

9:00 AM - 6:30 PM

We present medium resolution absorption spectroscopy (R ~ 6 km/s) of the CaII K-line (3933Å) recorded over a 5-night period towards the fast rotating stars HD 88195, HD 102647, HD 110411, HD 118232, HD 145964, HD 158643, HD 165459, and HD 183324. These observations have revealed significant daily variation in the level of absorption in the circumstellar gas disks that surround some of these stars. In addition, we have also observed transient absorptions that appear sporadically in these spectra that can be attributed to the passage of exo-comets as they approach the central star. Similar behavior has previously been recorded towards Beta Pic, HR 10 and HD 85905. Typically, such systems are < 10 Myr old and these observations thus allow us to witness the transition from a massive gaseous proto-planetary disk to a far less massive dusty debris disk in which large planetesimals are forming.

344.13 – **A Herschel-resolved Debris Disk Around the Nearby G Star HIP 32480**

Karl R. Stapelfeldt[1], G. Bryden[2], C. Eiroa[3], Herschel/DUNES Key Project Team

[1]*NASA Goddard Space Flight Center,* [2]*Jet Propulsion Laboratory, Caltech,* [3]*UA Madrid, Spain.*

9:00 AM - 6:30 PM

The Herschel Space Observatory is providing unprecedented sensitivity and angular resolution in the far-infrared. The DUNES Key Project (DUst around NEarby Stars, PI Carlos Eiroa) has finished its survey of 133 FGK stars within 25 pc of the Sun using the PACS photometer at 100 and 160 microns. We report the detection of a resolved debris ring around HIP 32480, a G0 star 16.5 parsecs distant. The ring is almost 300 AU in diameter and inclined 30 degrees from edge-on. We present a thermal emission model for the system that fits the Spitzer spectroscopy and Herschel images of the system. We find a minimum grainsize of ~4 microns in the main ring and a distinct warm dust population interior to it. Faint detached emission features just outside the ring may trace a separate, more distant ring in the system. The non-detection of the ring in archival HST/ACS coronagraphic images limits the dust grain albedo in the ring to be no more than 10%.

344.14 – **Binaries Among Debris Disk Stars**

David R. Rodriguez[1], B. Zuckerman[2]

[1]*Universidad De Chile, Chile,* [2]*UCLA.*

9:00 AM - 6:30 PM

We have gathered a sample of 112 main-sequence stars with known debris disks. We collected published information and performed adaptive optics observations at Lick Observatory to determine if these debris disks are associated with binary or multiple stars. We discover a previously unknown M-star companion to HIP 1185 at a projected separation of 628 AU. We find that 25% of our debris disk systems are binary or triple star systems, substantially less than the expected ~50%. The period distribution for these suggests a relative lack of systems with 1-100 AU separations. Only a few systems have blackbody disk sizes comparable to the binary/triple separation. Together, these two characteristics suggest that binaries with intermediate separations of 1-100 AU readily clear out their disks. We find that the fractional disk luminosity, as a proxy for disk mass, is generally lower for multiple systems than for single stars at any given age. Hence, for a binary to possess a disk or form planets it must either be a very widely separated binary with disk particles orbiting a single star or it must be a small separation binary with a circumbinary disk.

This research was supported in part by NASA grants to UCLA.

344.15 – **Modeling Self-Subtraction of Extended Emission in Angular Differential Imaging: Application to the HD 32297 Debris Disk**

Thomas Esposito[1], M. P. Fitzgerald[1], P. Kalas[2], J. R. Graham[2]

[1]*University of California, Los Angeles,* [2]*University of California, Berkeley.*

9:00 AM - 6:30 PM

We have spatially resolved the debris disk around the A star HD 32297 in scattered light using Keck NIRC2 coronagraphic imaging with adaptive optics in the H and K bands. We used angular differential imaging and the LOCI algorithm to suppress the stellar PSF and reveal the nearly edge-on disk. Although LOCI is effective in subtracting quasistatic speckles in the stellar PSF, its application can result in self-subtraction of the disk signal due to its finite spatial extent. The degree of self-subtraction varies with radius, which would preclude accurate measurement of the surface brightness profile and compromise our inferences regarding the physical processes responsible for the dust distribution. We have developed a new technique to model the effects of self-subtraction on spatially extended emission introduced by the LOCI-processed angular differential imaging. Our method accounts for both the self-subtraction kernel's dependence on LOCI parameters and spatial location. We forward model the structure of the disk and compute the form of the self-subtraction at each radius, and then use this to jointly extract the disk surface brightness, scale height, and midplane location as functions of radius. Our investigation into the inner structure of the disk recovers a previously reported brightness asymmetry. This may be indicative of a perturbed density distribution or a change in average grain properties due to a recent stochastic event. A comparison of the surface brightness and morphology of the disk between two wavelengths can provide insight into the size and distribution of dust grains as well as the grains' interaction with the surrounding environment. In addition, we can apply our self-subtraction modeling technique to future high-contrast imaging of this system and others like it. This work was supported in part by University of California Lab Research Program 09-LR-01-118057-GRAJ and NSF grant AST-0909188.

344.17 – **Modeling the HD 32297 Debris Disk with Far-IR Herschel Data**

Jessica Donaldson[1], A. Roberge[2]

[1]*Department of Astronomy, University of Maryland, College Park,* [2]*Exoplanets and Stellar Astrophysics Laboratory, NASA Goddard Space Flight Center.*

9:00 AM - 6:30 PM

SED modeling of debris disks is an important tool for revealing information about disk structure and the dust composition. Combining SED modeling and resolved imaging can constrain disk parameters and break degeneracies that plague SED modeling efforts. This allows us to constrain the location of the planetesimal belt and determine the composition of the dust grains. We apply these techniques to the disk of HD 32297. HD 32297 is a 30-Myr-old A0 star 112 pc away with a nearly edge-on debris disk that extends hundreds of AUs from the star. The HD 32297 debris disk has been resolved at several wavelengths (near-IR with HST NICMOS, mid-IR with Gemini South, and millimeter wavelengths with CARMA). We combine resolved imagery of the disk with archive data from Hipparcos, 2MASS, WISE, Spitzer, and IRAS to model the disk. Additionally, we use Herschel PACS data from the Gas in Protoplanetary Systems (GASPS) Open Time Key Programme. The PACS photometry at 70, 100, and 160 microns further constrains the SED, and the PACS spectroscopy places upper limits on

the gas abundance.

344.18 – **W2D2: WISE Warm Debris Disks Around Exoplanet-bearing Stars**

Farisa Y. Morales[1], M. W. Werner[1], G. Bryden[1], K. R. Stapelfeldt[2], D. L. Padgett[2]

[1]*JPL,* [2]*Goddard Space Flight Center.*

9:00 AM - 6:30 PM

We use Spitzer data and the WISE preliminary release to explore the incidence and relationship of warm dust in the habitable zones around exoplanet-host stars. We study the SED of about 300 planet-bearing stars to 1) identify excess emission at 12 and 22 microns (dust at ~300 and ~150 K), and 2) perform detailed photosphere-subtractions using Spitzer data of previously known warm disks.

Our project yields, the most extensive catalog of warm disks tracing events in the terrestrial-planet zones around exoplanet-host stars, providing observers an advantage for ground- and space-based follow-up imaging, and to inform next-generation mission designs.

344.19 – **Applying a New Polarization-based Diagnostic to an Existing Survey of Classical Be Stars**

Zachary H. Draper[1], J. P. Wisniewski[1], K. Bjorkman[2], X. Haubois[3], A. C. Carciofi[3], J. E. Bjorkman[2], M. R. Meade[4]

[1]*University of Washington,* [2]*University of Toledo,* [3]*Universidade de São Paulo, Brazil,* [4]*University of Wisconsin-Madison.*

9:00 AM - 6:30 PM

Classical Be stars are middle-aged, massive B-class stars which rotate rapidly near their critical rate. Through a yet unknown mechanism material is ejected from the star into a circumstellar disk. The density distribution of material within these disks can be diagnosed by studying the polarization signature. A survey of Classical Be stars was conducted by the Pine Bluff Observatory (PBO) using the HPOL instrument from 1989 to 2004, which cataloged optical spectropolarimetry for 75 Be stars. This survey was further supplemented with UV spectropolarimetry from the WUPPE instrument aboard the Astro-1 and Astro-2 Space Shuttle missions. We have developed an IDL-based pipeline to remove interstellar polarization caused by dust along the line of sight to each star for a subset of the survey, thereby allowing us to measure the intrinsic polarization variations due to changes within the disk. We apply a newly-developed diagnostic of the Balmer jump vs V-band polarization to help us better understand the mechanism(s) which causes these stars to form circumstellar disks. We also discuss constraints on axial precession and complex density morphologies.

344.20 – **The Balmer Decrement in Be Stars**

Christina Aragona[1], M. V. McSwain[1], A. Marsh Boyer[1]

[1]*Lehigh University.*

9:00 AM - 6:30 PM

Classical Be stars are non-supergiant B stars that have exhibited emission in their photospheric lines generated by a circumstellar disk formed by material ejected from the stellar surface. In order to investigate the relationship between observed emission in the H Balmer lines and the physical properties of the disks, we present optical spectra of Be/XRBs, cluster, and field Be stars covering Hα through Hδ. We use Hα emission to determine disk presence and strength. We then search for correlations in the profiles of Hβ through Hδ with Hα strength and the star's environment (binary vs. cluster member vs. field). To compliment these observations, we are developing models to examine the effects of disk temperature, density, radius, and inclination angle on the shape of the line profile. We assume a steady state, geometrically thin disk rotating with Keplerian motion. Our goal is to combine these disk models with available TLUSTY NLTE models of B star atmospheres to accurately reproduce our observations.

We are grateful for support from NSF grant AST-1109247, NOAO student support, and Lehigh University.

344.21 – **The Spectral Energy Distributions of the Be Stars of *h* and χ Persei**

Amber Nichole Marsh Boyer[1], M. McSwain[1], T. Currie[2], C. Aragona[1]

[1]*Lehigh University,* [2]*NASA-Goddard Space Flight Center.*

9:00 AM - 6:30 PM

Classical Be stars host circumstellar disks composed of material ejected from the stellar surface during outburst events. Upwards of 30% of the brightest B-type stars in *h* and χ Per are known to be Be stars, thus providing an excellent laboratory for investigating the physical characteristics of these disk structures. Here we conduct a preliminary study of the cluster Be star disk physical properties and present their spectral energy distributions (SEDs). We compare optical and infrared photometry from WEBDA, 2MASS, *WISE*, *Spitzer*, and *IRAS* to Tlusty BSTAR2006 model SEDs based on our earlier measurements of the stellar photospheres. Using simple, reddened blackbody models we examine the disk contribution to the system flux and estimate the disk temperature.

We are grateful for support provided through NSF grant AST-1109247 and Lehigh University. A. N. Marsh Boyer is also supported by a Grant-In-Aid of Research from the National Academy of Sciences, administered by Sigma Xi.

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344.22 – **Imaging Disk Distortion Of Be Binary System δ Scorpii Near Periastron**

Xiao Che[1], J. Monnier[1], F. Baron[1], S. Kraus[1], E. Pedretti[2], N. Thureau[3], T. ten Brummelaar[4], H. McAlister[4], S. Ridgway[5], N. Turner[4], J. Sturmann[4], L. Sturmann[4]

[1]*University of Michigan,* [2]*ESO, Germany,* [3]*University of St. Andrews, United Kingdom,* [4]*The CHARA Array, Georgia State University,* [5]*National Optical Astronomy Observatory.*

9:00 AM - 6:30 PM

The highly-eccentric Be binary system δ Sco was expected to reach periastron during early July 2011, when the distance between the primary and secondary was about a few times of the size of the primary disk. This opens a window to study the structure of gaseous disks around Be stars and how the disks respond to gravitational disturbance. Long-baseline multi-beam (≥ 3) interferometry allows us to reconstruct images of the star-disk system, which is independent of simplified models. We carried out 7 nights of H-band high angular resolution interferometric observations with the newly-commissioned 6-telescope mode of the MIRC combiner at CHARA one week after the predicted periastron date. We will present the first imaging results of the disk before and after the close-periastron interaction and discuss the the origin of the Be star phenomena

344.23 – **Be Stars: Comparing Two Techniques to Determine Disk Size**

Erika Grundstrom[1], D. R. Gies[2]

[1]*Vanderbilt University and Fisk University,* [2]*Georgia State University.*

9:00 AM - 6:30 PM

Be stars are rapidly rotating B-type stars that lose mass in an equatorial, circumstellar disk (Porter & Rivinius 2003). A fundamental measurement Be star observers desire is the size of this circumstellar disk and the ability to obtain that size with the greatest ease possible. In this poster, we present a comparison of the Grundstrom & Gies (2006) method using the measurement of the equivalent width of H-alpha and the Huang (1972) method of using the measurement of peak separation (which is not useful for stars that have no separate peaks i.e., those that are inclined toward us and those that have copious disks). We discuss dependences on temperature and inclination as well.

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345 – Stars, Cool Dwarfs, Brown Dwarfs

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

345.01 – **Fundamental Properties of Main-Sequence Stars**

Tabetha S. Boyajian[1], K. von Braun[2], H. McAlister[1], J. Jones[1], G. van Belle[3], D. Gies[1], T. ten Brummelaar[1], G. Schaefer[1], R. White[1], S. Ridgway[4], T. Staff[1]

[1]*Georgia State UNIV./CHARA,* [2]*Caltech,* [3]*Lowell Observatory,* [4]*NOAO.*

9:00 AM - 6:30 PM

The CHARA Array is a long baseline optical/infrared interferometer, uniquely suited to measure the angular diameters of stars. In this presentation, we summarize the current results of a survey measuring diameters of nearby, main-sequence stars. This project consists of the most accurate and largest homogeneous data set that provides direct measurements of the stellar linear radius and effective temperature for stars of this type. We highlight the challenges these data bring to current stellar atmospheric and evolutionary models, as well as newly defined empirically based relations to the stellar effective temperature and radius.

345.02 – **Results from the Nearby Stars (NStars) Program**

Christopher J. Corbally[1], R. O. Gray[2], R. Jeck[1]

[1]*Vatican Observatory,* [2]*Appalachian State U..*

9:00 AM - 6:30 PM

Progress is continuing toward a final omnibus publication containing new precise spectral types, basic physical parameters, and (where relevant) measures of the chromospheric activity for the 3600 stars earlier than M0 within 40 parsecs of the Sun. In this poster we review recent improvements in the derivation of the basic physical parameters (Teff, log(g), [M/H], and microturbulent velocity) via fits to model fluxes and spectra, and in the transformation of our measures of chromospheric activity to the Mount Wilson system.

345.03 – **The Young Solar Analogs Project**

Richard O. Gray[1], J. M. Saken[2], C. J. Corbally[3], M. F. Seeds[1], S. S. Morrison[1]

[1]*Appalachian State Univ.,* [2]*Marshall University,* [3]*Vatican Observatory Research Group.*
9:00 AM - 6:30 PM

We are carrying out a long-term project of measuring chromospheric activity and brightness variations in 31 young solar analogs (YSAs) using the Dark Sky Observatory (DSO -- Appalachian State University) 32-inch telescope and the G/M spectrograph. These YSAs are solar-type (spectral types F8 - K2) stars with ages ranging from 0.3 - 1.5 Gyr. The goal of this project is to gain better understanding of the magnetic activity of the early Sun, and especially how that activity may have impacted the development of life on the Earth. This project will also yield insights into the space environments experienced by young Earth analogs. We are currently in our 5th year of obtaining Ca II K & H chromospheric flux measurements, and are beginning to see signs of long-term activity cycles in a number of our stars. In addition, rotational modulation of the chromospheric fluxes is detectable in our data, and we have determined rotational periods for many of our stars. Short timescale increases in the K & H fluxes have been observed in a number of our stars; these events may be related to stellar flares. VATTSpec, a new moderate-resolution spectrograph on the 1.8-m Vatican Telescope in Arizona, has recently become involved with the project. This spectrograph will increase our ability to detect short-term changes in stellar activity on timescales of hours to minutes. We have been monitoring the program stars for one year in a multi-band photometric system consisting of Stromgren-v, and Johnson B, V, and R filters. We will soon add a narrow-band H-alpha filter to the system. Photometry is being carried out with a small piggy-back telescope on the 32-inch, but a robotic photometric telescope is currently being installed at DSO for this purpose. This project is supported by the National Science Foundation.

345.04 – **Harnessing the Power of NASA's Kepler Mission for Understanding Stellar Activity and Enhancing Planet Discovery**

Fabienne A. Bastien[1], K. G. Stassun[1], J. Pepper[1], L. Walkowicz[2], G. Basri[3], K. G. Carpenter[4]

[1]*Vanderbilt University,* [2]*Princeton University,* [3]*University of California at Berkeley,* [4]*NASA Goddard Space Flight Center.*
9:00 AM - 6:30 PM

The magnetic activity of stars, which often manifests itself in the form of starspots, can induce short-timescale photometric variability, thereby adding to the difficulty of detecting planets, particularly those in the Earth mass range. Indeed, photometric “noise” caused by stellar magnetic activity can 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 the transit method, the exoplanet community needs a way characterize the photometric stability of a star in advance. The goal of our project is to empirically relate chromospheric activity and photometric variability for a large sample of stars, spanning a range of stellar masses and evolutionary states, in order to develop an index that is predictive of stellar photometric variability. The inclusion of stars with a range of known rotation periods, as well as subgiants, giants, and Kepler asteroseismology targets, will allow us to more finely examine the relationship between a star's age and its magnetic activity. This work will aid in a fundamental understanding of the physics of magnetic activity in solar-type stars. We acknowledge support through NSF PAARE grant AST-0849736.

345.05 – **Spectroscopically Determining Fundamental Properties Of M Dwarfs**

Michael Bottom[1], J. Pineda[1], J. A. Johnson[1]

[1]*California Institute of Technology.*
9:00 AM - 6:30 PM

We present a method of measuring masses and metallicities of M dwarfs using optical spectroscopy, without parallax and photometry. We co-add hundreds of Keck/HIRES spectra of nearby M dwarfs with known parallaxes, and use these extremely high signal-to-noise templates to derive a calibration between spectral indices and the physical properties of the stars. We have applied this method to low-mass Kepler Objects of Interest (KOIs) in order to better estimate stellar, and hence planet, properties. Our methodology is applicable to M dwarfs both in the solar neighborhood and throughout the Galaxy.

345.06 – **A Standard Star System For Intermediate-band Cah Photometry: Sara U42a And Nuro Data**

Chelsea Spengler[1], L. Farris[2], T. Robertson[3]

[1]*Case Western Reserve University,* [2]*Missouri State University,* [3]*Ball State University.*
9:00 AM - 6:30 PM

This project uses a technique to solve for four transformation coefficients simultaneously for multiple nights of observations and a nightly zeropoint value. The observed values are transformed to a standard system based on the R and (R-I) Landolt standards and the instrumental (R-L) (CaH) color of the U42a system on the 0.9-meter telescope operated by the Southeastern Association for Research in Astronomy (SARA). Transformation coefficients are calculated for observations of standard and program stars from the Lowell 0.78-meter telescope operated by the National Undergraduate Research Observatory (NURO). The transformed NURO standard star observations are compared to those using the U42a system. Likewise, the NURO program stars are compared to matching stars observed with SARA's U55 camera, which has also been transformed to the standard system. We find that all the observations agree well and have been successfully converted to the standard system. The implementation of this new system will allow for greater ease when separating red dwarfs and giants using the (R-L) and (R-I) colors, and may permit more accurate modeling of absolute magnitudes for late M dwarfs as a function of (R-I).

345.07 – **Searching for Treasure in the South: Red Dwarfs within 25 Parsecs**

Altonio D. Hosey[1], J. G. Winters[1], M. R. Boyd[1], S. B. Dieterich[1], C. T. Finch[2], N. C. Hambly[3], T. J. Henry[1], P. A. Ianna[4], W. Jao[1], A. R. Riedel[1], J. P. Subasavage[5]

[1]*Georgia State University,* [2]*United States Naval Observatory,* [3]*University of Edinburgh, United Kingdom,* [4]*University of Virginia,* [5]*Cerro Tololo Inter-american Observatory, Chile.*
9:00 AM - 6:30 PM

We describe the RECONS (REsearch Consortium On Nearby Stars) effort to find the missing red dwarf star systems in the solar neighborhood, defined here to be those closer than 25 parsecs. Knowing that there are currently 37 red dwarf systems known within 5 parsecs, and assuming a constant density of star systems in the solar neighborhood, we predict there to be roughly 4600 red dwarf star systems within 25 parsecs. But how many have been identified? Here we present results of our comprehensive reconnaissance of the southern sky, focused on red dwarf systems having proper motions in excess of 0.18"/yr. Using BRI plate magnitudes from the SuperCOSMOS Sky Survey and photometry from 2MASS, we have found 1711 star systems estimated to be within 25 parsecs, or 74% of the anticipated 2300 systems in the southern sky. However, 1041 of the star systems do not have the trigonometric parallaxes required to verify their proximity. Since 1999, we have been obtaining accurate VRI photometry at the CTIO 0.9m to improve distance estimates (also in concert with 2MASS photometry), and measuring trigonometric parallaxes for the closest systems. Here we provide a census of the southern red dwarf systems, which span V magnitudes of 7.3 to 20.4. At present, the 25 parsec census includes ~750 systems with plate distance estimates, ~270 systems with CCD distance estimates, and ~660 systems with trigonometric parallaxes, for a total of ~1700 systems. These nearby red dwarfs will be the fundamental sample to inform us about the stellar content of the Milky Way, and provide the benchmark luminosity and mass functions against which star formation scenarios must be reconciled.

This effort is supported by the NSF through grants AST-0908402 and AST-1109445, and via observations made possible by the SMARTS Consortium.

345.08 – **The Optical-IR Color-Magnitude Sequence Around the Hydrogen Burning Mass Limit: Optical Photometry and Trigonometric Parallaxes for Nearby M and L Dwarfs**

Sergio Dieterich[1], T. J. Henry[1], A. D. Hosey[1], W. Jao[1], J. G. Winters[1], RECONS

[1]*Georgia State University.*
9:00 AM - 6:30 PM

Accurate placement in an HR diagram is necessary for the characterization of any stellar, or substellar, population. Here we extend the coverage of optical/IR color-magnitude diagrams to provide a continuous sequence for stars like the Sun through the mid L spectral sub-types. We present new trigonometric parallaxes obtained at the CTIO 0.9m telescope through the RECONS (REsearch Consortium On Nearby Stars, www.recons.org) astrometry program, and new VRI photometry obtained at the CTIO 0.9m and SOAR 4m telescopes. We demonstrate how optical/IR color combinations, in particular (V-K), are useful in breaking the degeneracies in color-magnitude diagrams containing only IR colors. One of the key results of this work is a set of improved color-absolute magnitude relations that can be used to make accurate distance estimates for objects straddling the hydrogen-burning limit. We also discuss objects thought to be young, multiple, or metal poor based on their outlying locations in the sequence.

This effort is supported by the NSF through grant AST-0908402, via observations made possible by the SMARTS Consortium, and is based in

part on observations obtained at the Southern Astrophysical Research

(SOAR) telescope, which is a joint project of the Brazilian Ministry of Science and Technology, the U.S. National Optical Astronomy Observatory, the University of North Carolina at Chapel Hill, and Michigan State University.

345.09 – **Trigonometric Parallax Measurements from the MEarth Survey**

Jason Dittmann[1], J. M. Irwin[2], Z. K. Berta[1], D. Charbonneau[1], T. MEarth Team[1]

[1]*Harvard University,* [2]*Smithsonian Center for Astrophysics.*
9:00 AM - 6:30 PM

The MEarth Survey is a northern hemisphere transit survey observing 2000 of the closest, high proper motion mid-to-late M Dwarfs at a typical cadence of 20 minutes cadence in an effort to detect small rocky type planets whose atmospheres are readily accessible for study with today's instrumentation. For a subset of the target sample, we

have already obtained more than a hundred images per target and a baseline of a year or more. Due to the proximity of the target stars and the large amount of data, the MEarth data set lends itself well to astrometric studies. We have embarked on measuring the trigonometric parallax for all the stars in the MEarth survey. Of the 2000 stars targeted, only approximately 1/6 had previously measured parallaxes at the beginning of the survey. Using this subsample as a test of feasibility and the quality of our astrometry, we can reliably reproduce the previously observed parallaxes using the MEarth data. If we succeed in our quest to measure trigonometric parallaxes for all 2000 MEarth-North stars by the end of the survey, we will have refined considerably the map of the low mass stars in the solar neighborhood. The MEarth team gratefully acknowledges funding from the David and Lucile Packard Fellowship for Science and Engineering and the National Science Foundation under grant number AST- 0807690.

345.10 – **A Qualitative Analysis Of The High-precision Long-cadence Photometry Of A Sample Of Kepler Dm Stars**

Sai Gouravajhala[1], E. Guinan[1], S. Engle[1]

[1]*Villanova University.*
9:00 AM - 6:30 PM

Dwarf M (dM) stars are the most common stars in the Universe making up about 75% of stars in the solar neighborhood. Because of their ubiquity and possible hosts to many planets, it is of critical importance to understand their various physical properties. We report on a preliminary study of a sample of over 350 dM stars contained in the Kepler MAST archive. By analyzing the long-cadence, high precision Kepler photometric data, we were able to calculate probable rotation periods from starspot modulation of the light (using the Online NStED Periodogram service) and light amplitudes for these stars. We categorized these light curves based on their shapes, which enables us to compare and contrast features, such as spot behavior and white-light flares. A qualitative analysis of these light curves yields a plethora of information regarding differential rotation, spot evolution (including starspot growth and decay), magnetic activity (in the form of white-light flares), and age. By using the Age-Activity-Rotation relationship developed by Engle and Guinan (2011) as part of the Living with a Red Dwarf Program, we were able to determine ages for this group. By looking at the physical properties of these dM stars, we build on the continuing efforts to understand the information these properties tell us about dM star evolution.

This research is supported by NSF/RUI Grant AST-1009903 which we gratefully acknowledge.

345.11 – **Observational Exploration of M dwarf Dynamos**

Randall Hamper[1], K. Honeycutt[1], QUEST2 Collaboration

[1]*Indiana University.*
9:00 AM - 6:30 PM

For the Sun and higher mass M dwarfs, the magnetic field is understood to be anchored at the boundary between the convective and radiative zones. For lower mass fully convective M dwarfs, another type of dynamo must be at work. Examining the chromospheric activity from M dwarfs with a range of masses to test for a change in the character of chromospheric activity yields interesting clues to the nature of the dynamos within fully convective stars. One method to examine the character of the chromospheric activity is a measurement of the degree of variability of the target stars compared to nearby photometrically stable companion stars of like brightness. Measurement of the degree of variability showed that for V-I less than 3.6 the target stars displayed a degree of variability ranging from equal to 20 times greater than companion stars. While for targets stars with V-I greater than 3.6, the degree of variability was equal to that displayed by companion stars. With all the targets stars of V-I greater than 3.6, demonstrating chromospheric activity, the lack of variability may indicate that chromospherically active regions are evenly distributed. Additionally each target star was examined for any periodic behavior in its variability. For 30 stars within the sample, periods were found ranging from around 20 days upwards to 45 days. With a majority published values of Praesepe M dwarf rotational periods being smaller than the range seen within this study, these periods may represent another type of periodicity within active M dwarfs.

345.12 – **Planets and Brown Dwarfs and Stars, Oh My! --- Companions Along the Road to the Nearest Stars**

Todd J. Henry[1], C. L. Davison[2], S. B. Dieterich[2], P. A. Ianna[1], W. C. Jao[2], D. W. Koerner[3], J. P. Subasavage[4], A. M. Tanner[5], R. J. White[2], RECONS

[1]*RECONS,* [2]*Georgia State University,* [3]*Northern Arizona University,* [4]*USNO,* [5]*Mississippi State University.*
9:00 AM - 6:30 PM

RECONS (www.recons.org, REsearch Consortium On Nearby Stars) has been using astrometric techniques since 1999 to search for massive planets orbiting more than 130 nearby red and white dwarfs. Because of their proximity, nearby stars are natural locations to search for other solar systems --- the stars provide increased fluxes, larger astrometric perturbations, and higher probabilities for eventual resolution of planets than similar stars at larger distances. Unlike radial velocity searches, our astrometric effort is most sensitive to Jovian planets in Jovian orbits, i.e. those that span decades. We have discovered stellar companions with masses of a few hundred Jupiters, brown dwarf companions with masses of a few tens of Jupiters, and are now pushing into the realm of planets with masses of a few Jupiters around the nearest red dwarfs. Several previously unknown companions have been imaged via Gemini-AO observations, but we have also detected perturbations caused by enigmatic companions that elude direct detection. As we sweep through the mass regimes of stars to exoplanets for companions, we are now able to assess the various populations --- stars are common as companions, whereas brown dwarfs and massive planets are rare. We outline what we have discovered so far and place our exoplanet search results in context with an overview of the census of more than 60 stars with exoplanets known within 25 pc.

This effort is supported by the NSF through grant AST-0908402 and via observations made possible by the SMARTS Consortium.

345.13 – **Eleven Wide, Very-Low-Mass Companions to Nearby High Proper Motion Stars Discovered with WISE**

Daniel P. Dutcher[1], A. C. Mennen[2], S. Lepine[3], J. Faherty[3]

[1]*Washington University,* [2]*College of William and Mary,* [3]*American Museum of Natural History.*
9:00 AM - 6:30 PM

As the only all-sky infrared survey since 2MASS, WISE presents the first opportunity to search for low mass companions using common proper motion. We have searched around stars from the LSPM-north and LSPM-south catalogues of stars with proper motions larger than 0.15 seconds of arc per year, comparing the 2MASS and WISE positions of all sources within 1 minute of arc. As a result we have discovered 11 new very-low-mass, wide companions to LSPM stars, with a very low probability of these being the result of a chance alignment. Our search has also recovered 5 previously known very-low-mass companions. Our search for common proper motion companions to high proper motion stars now extends over 57% of the sky. Infrared colors suggest the companions are M8-M9 dwarfs, near the hydrogen-burning limit; spectroscopic observations will be required for formal spectral classification of the companions.

345.14 – **Candidate Very-Low-Mass Companions to Nearby Stars Found in the WISE Survey**

Anne Mennen[1], D. Dutcher[2], S. Lepine[3], J. Faherty[3]

[1]*American Museum of Natural History, The College of William and Mary,*

[2]*American Museum of Natural History, Washington University in St. Louis,*

[3]*American Museum of Natural History.*
9:00 AM - 6:30 PM

We report the identification in the Wide-Field Survey Explorer (WISE) preliminary release of 36 probable very-low-mass companions to nearby stars from the SUPERBLINK proper motion catalogue. We examined all WISE sources within one arcminute of a subset of 156,000 SUPERBLINK stars with proper motions between 0.040 and 0.015 seconds of arc per year, photometric distances within 100 parsecs, and positions at least seven degrees from the galactic plane. Using proper motions calculated by comparing the WISE positions of the sources to those of their counterparts in the 2MASS Catalogue, we identified all WISE sources sharing a common proper motion with the SUPERBLINK star. We eliminated all sources detected in the Palomar Sky Survey blue plates, keeping only those red enough to be low-mass or brown dwarf companions. We used WISE and 2MASS colors to select only objects consistent with being M, L, or T dwarfs, leaving only 36 likely companions. Based on their color and assumed distances, we estimate the 36 low-mass companions to be either late M or early L dwarfs. Follow-up spectroscopic observations will be required for confirmation and formal spectral classification of the companions. We acknowledge the American Museum of Natural History and the National Science Foundation for their support.

345.15 – **The EBLM Project: Defining The M Dwarf Mass-radius Relation As A Function Of Activity And Metallicity Using F/G/K + M Dwarf Eclipsing Binaries**

Leslie Hebb[1], Y. Gomez Maqueo Chew[2], D. Pollacco[2], K. Stassun[1], A. Collier Cameron[3]

[1]*Vanderbilt University,* [2]*Queen's University, Belfast, United Kingdom,* [3]*St Andrews University, United Kingdom.*
9:00 AM - 6:30 PM

The most accurate direct measurements of fundamental stellar properties are from eclipsing binary (EB) stars. Eclipsing binaries are thus central to calibrating stellar evolution models and defining empirical relationships which are used in many areas of research. However, one of the most compelling problems to arise in the last few years is the reported discrepancy between the observed and theoretically predicted radii and temperatures of M dwarf stars. This problem manifests itself in many different objects and kinds of analyses including short period EBs, interferometric radius measurements, active field M dwarfs, and more recently in one very long period M dwarf EB. Furthermore, the discrepancy is observed over a range of masses from K-dwarfs down to the bottom of the main sequence. In order to explore this problem, we have an ongoing program to examine the mass-radius relation of M dwarfs as a function of

metallicity and activity using a large sample of EBs composed of an F, G or K dwarf primary star and an M dwarf secondary. Here, I describe our project and give some preliminary results.

345.16 – **Hα Variability in Active Equal-Mass M Dwarf Wide Binaries**

Heather C. Gunning[1], S. J. Schmidt[1], J. R. A. Davenport[1], S. L. Hawley[1], S. Dhital[2]

[1]*University of Washington,* [2]*Vanderbilt University.*

9:00 AM - 6:30 PM

We present monitoring of equal-mass, active mid-M dwarf wide binaries using the mid-resolution optical spectrograph on the Astrophysical Research Consortium 3.5-m telescope. We selected our sample for spectroscopic follow-up from the Sloan Low-mass Wide Pairs of Kinematically Equivalent Stars (SLoWPoKES) catalog. Our goal is to examine the differences in activity level, as measured by the equivalent width of Hα, of stars of similar masses, metallicities, and ages. We will compare both the mean and the normalized variability of Hα between the companions of each of our wide binary pairs. Additionally, we will examine the variation in molecular bands, such as the temperature-sensitive TiO feature, over time.

345.17 – **Recalibration of the M star ζ Metallicity Index Using Common Proper Motion Systems**

Matthew Wilde[1], S. Lepine[1]

[1]*American Museum of Natural History.*

9:00 AM - 6:30 PM

M dwarfs and subdwarfs comprise 70% of the stellar population of the Galaxy, and their main sequence lifetimes are longer than the Hubble time, which potentially makes them powerful tracers of the chemical and dynamical evolution of the Milky Way if their metallicities can be estimated from simple measurements. The ζ(TiO/CaH) index, which measures the relative strengths of the TiO and CaH bands in M stars, can be used to estimate the metallicity of M dwarfs using low-resolution optical spectra. The index is currently used to divide main-sequence M stars into four metallicity subclasses: dwarfs (dM), subdwarfs (sdM), extreme subdwarfs (esdM), and ultrasubdwarfs (usdM). As a means to verify the calibration of the ζ(TiO/CaH) index across spectral subtypes, we have obtained optical spectra of 143 wide M + M binaries, identified as common proper motion doubles in the LSPM-north catalog. Using the pairs as equal-metallicity calibrators, we have revised the definition of ζ(TiO/CaH). The new calibration will improve metallicity estimates of low mass main sequence stars, without the need for high-resolution optical spectroscopy. In addition, we have updated the relationship between spectral subtype and each of the the CaH2, CaH3, TiO5, TiO6 and TiO7 spectral indices, using measurements from high signal-to-noise, empirical classification templates. The revised relationships will improve metallicity and effective temperature estimates of M dwarfs in upcoming optical spectroscopic surveys.

345.18 – **Wide Low-Mass Tertiary Companions of Binary Star Systems as a Test of Star Formation Theories**

Stephanie Douglas[1], P. Allen[2]

[1]*Franklin & Marshall College,* [2]*University of Pennsylvania/Franklin & Marshall College.*

9:00 AM - 6:30 PM

We will present the status of a common proper motion search for wide low-mass stellar and sub-stellar companions to known white dwarf-M dwarf binary systems. I-band observations were made using the 31" NURO telescope at Lowell Observatory. Candidate companions are selected using astrometry from our own data and 2MASS photometry. We have begun to spectroscopically confirm candidates that pass our selection criteria. The ultimate goal of the search is to test star formation theories which predict that close binary systems form by transferring angular momentum to a third companion. To this end, we will model the physical companion population and perform Bayesian statistical analysis to determine the best-fit population model to our data. Here we will present our spectroscopically confirmed companions as well as the preliminary results of our population models and statistical analysis.

345.19 – ***Kepler* Cycle 1 Observations of Low Mass Stars: New Eclipsing Binaries, Single Star Rotation Rates, and the Nature and Frequency of Starspots**

Thomas E. Harrison[1], J. L. Coughlin[1], N. M. Ule[1], M. Lopez-Morales[2]

[1]*New Mexico State Univ.,* [2]*Institut de Ciencies de L'Espai, Spain.*

9:00 AM - 6:30 PM

We have analyzed *Kepler* light curves for 849 stars with $T_{eff} < 5200$ K from our Cycle 1 Guest Observer program. We identify six new eclipsing binaries, one of which has an orbital period of 29.91 d, and two of which are probable W UMa variables. In addition, we identify a candidate "warm Jupiter" exoplanet. We further examine a subset of 670 sources for variability. Of these objects, 265 stars clearly show periodic variability that we assign to rotation of the low-mass star. At the photometric precision level provided by *Kepler*, 251 of our objects showed no evidence for variability. We were unable to determine periods for 154 variable objects. We find that 79% of stars with $T_{eff} < 5200$ K are variable. The rotation periods we derive for the periodic variables span the range $0.31 < P_{rot} < 126.5$ d. A considerable number of stars with rotation periods similar to the solar value show activity levels that are 100 times higher than the Sun. This is consistent with results for solar-like field stars. As has been found in previous studies, stars with shorter rotation periods generally exhibit larger modulations. This trend flattens beyond $P_{rot} = 25$ d, demonstrating that even long period binaries may still have components with high levels of activity and investigating whether the masses and radii of the stellar components in these systems are consistent with stellar models could remain problematic. Surprisingly, our modeling of the light curves suggests that the active regions on these cool stars are either preferentially located near the rotational poles, or that there are two spot groups located at lower latitudes, but in opposing hemispheres.

Acknowledgements: Funding for the *Kepler* mission is provided by NASA's SMD. The authors are supported under NASA grant NNX10AC40G. JLC is supported through an NSF GRFP.

345.20 – **Very Low Mass Companions from the First Two Years of SDSS-III MARVELS**

Nathan M. De Lee[1], J. Ge[2], S. Gaudi[3], B. Lee[2], S. Fleming[4], B. Ma[2], K. Stassun[5], E. Agol[6], J. Pepper[5], D. C. Nguyen[2], L. Hebb[5], J. Wisniewski[6], S. Mahadevan[7], J. Crepp[8], B. Zhao[2], L. Ghezzi[9], C. Reyle[10], B. Santiago[11]

[1]*University of Florida, Vanderbilt University,* [2]*University of Florida,* [3]*Ohio State University,* [4]*University of Florida, Penn State University,* [5]*Vanderbilt University,* [6]*University of Washington,* [7]*Penn State University,* [8]*Caltech,* [9]*Observatório Nacional/LIneA, Brazil,* [10]*Besancon Observatory, France,* [11]*IF/UFRGS, Brazil.*

9:00 AM - 6:30 PM

The SDSS-III MARVELS survey is a comprehensive radial velocity survey of 3,300 nearby F through K stars, between magnitudes $7.6 < V < 12.0$. The primary goal of this survey is to search for planets among a homogeneous set of stars, which will be used to put constraints on formation and evolution models. This survey is also very sensitive to more massive companions such as brown dwarfs and low mass binaries. We will discuss an ongoing project aimed at characterizing the properties of these very low-mass stellar and substellar (VLMSS) companions with minimum masses between 20 and 100 Jupiter masses. As part of the first two years of the MARVELS project 2,580 stars were searched for VLMSS companions with periods from 1.1 to 360 days using a modified Lomb-Scargle periodogram, yielding ~12 VLMSS companions. This poster details the spectroscopic and imaging follow-up of these VLMSS companions, and presents an overview of our meta-study to determine the nature of the 'brown dwarf desert' including the role of parameters like host-star spectral type and metallicity. Finally, this large homogeneous radial velocity survey will be placed in the larger context of our current knowledge about VLMSS statistics.

This work was supported by the W.M. Keck Foundation, NSF, SDSS-III collaboration, NASA, and UF.

345.21 – **Searching for Partners of Cool Senior Citizens**

Wei-Chun Jao[1], T. J. Henry[1]

[1]*Georgia State University.*

9:00 AM - 6:30 PM

Mass is one of the most fundamental parameters in stellar astronomy. In order to measure dynamical masses, one needs to find nearby binary systems that can be resolved and monitored, ideally with orbital periods that completely wrap in a reasonable amount of time. Many surveys have been made of nearby main sequence dwarfs, and their mass-luminosity relation is well established. As part of our Cool Subdwarf Investigations (CSI) program, we are searching for subdwarf binaries of spectral types K and M within 60 parsecs to measure their multiplicity rate and to reveal binaries appropriate for mass determinations. Here we present results of our CSI work using HST's Fine Guidance Sensors. When combined with previous CSI work and results in the literature, we find the multiplicity rate of subdwarfs, 21%, to be surprisingly low compared to that of similar main sequence K and M stars, 37%. This work has several implications, including that the star formation and/or evolution history of subdwarfs is different than for dwarfs, and that ideal systems for subdwarf mass determinations are difficult to find.

This work is supported by HST grant GO-11943.

345.22 – **Angular Momentum Loss in Subdwarf B + dwarf M Binaries**

Donald M. Terndrup[1], N. Karnath[2], C. Epstein[1], M. Pinsonneault[1], J. O. Djordjevic[3]

[1]*Ohio State Univ.,* [2]*Northern Arizona University,* [3]*Clemson University.*

9:00 AM - 6:30 PM

We present new optical and infrared photometry of several short-period (P ~ 2.5 h) eclipsing binaries consisting of a hot subdwarf B star and a dwarf M star. Observations of open clusters yield estimates of the angular momentum loss from magnetized winds in rapidly-rotating low-mass stars. We combine our data with eclipse timings from the literature to detect or set strong limits on changes in the orbital period that result from angular momentum loss in these binaries, and compare these with expectations from

empirically calibrated wind-loss models.

345.23 – **A Search for Fine Wines: Discovering Close Red Dwarf-White Dwarf Binaries**

Mark Boyd[1], C. T. Finch[2], N. C. Hambly[3], T. J. Henry[1], W. Jao[1], A. R. Riedel[1], J. P. Subasavage[4], J. G. Winters[1], RECONS

[1]*Georgia State University,* [2]*United States Naval Observatory,* [3]*University of Edinburgh, United Kingdom,* [4]*Cerro Tololo Inter-American Observatory, Chile.*
9:00 AM - 6:30 PM

Like fine wines, stars come in both red and white varieties. Here we present initial results of the Fine Wines Project that targets red dwarf-white dwarf pairs. The two scientific goals of Fine Wines are (1) to develop methods to estimate ages for red dwarfs based on the cooling ages of the white dwarfs, and (2) to identify suitable pairs for dynamical mass determinations of white dwarfs to probe their interior structures. Here we focus on the search for Fine Wines, including sample selection, elimination of false positives, and initial reconnaissance. The sample was extracted via color-color plots from a pool of more than 30,000 proper motion systems examined during the SuperCOSMOS-RECONS (SCR) and UCAC3 Proper Motion (UPM) surveys. The initial sample of 75 best candidates is being observed for BVRI photometry and 3500-9500 A spectroscopy to confirm whether or not the systems are red dwarf-white dwarf pairs. Early results indicate that roughly 50% of the candidates selected are indeed Fine Wine systems.

This effort is supported by the NSF through grant AST 09-08402 and via observations made possible by the SMARTS Consortium.

345.24 – **A USNO Search for Astrometric Companions to Brown Dwarfs**

Jennifer L. Bartlett[1], F. J. Vrba[1], J. A. Munn[1], C. B. Luginbuhl[1], T. Tillemann[1], A. A. Henden[2]

[1]*US Naval Observatory,* [2]*American Association of Variable Star Observers.*
9:00 AM - 6:30 PM

Preliminary analyses of ten brown dwarfs observed by the U.S. Naval Observatory infrared parallax program show no indication of astrometric perturbations due to low mass companions. The data were collected using ASTROCAM on the 1.55-m Strand Astrometric Reflector from 2000 September through 2006 April over periods from 3.0 to 5.4 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 in the late L and mid- to late-T ranges, including one L subdwarf. None are known binaries. Preliminary parallaxes place them within 30 pc; half of these are probable members of the Solar Neighborhood because they lie within 25 pc, including two within 10 pc. These substellar objects are located north of -25° Dec. and lie between 0^h and 9^h in R.A.

The brown dwarfs evaluated are 2MASS J00303013-1450333, 2MASS J02431371-2453298, 2MASS J03284265+2302051, 2MASS J04151954-0935066, 2MASS J05160945-0445499, 2MASS J05325346+8246465, 2MASS J05591914-1404488, 2MASS J07271824+1710012, 2MASS J07554795+2212169, and 2MASS J08251968+2115521. Analyses of 39 more brown dwarfs are planned.

345.25 – **The CFHT Infrared Astrometry Program: High-Precision Parallaxes for Ultracool Dwarfs**

Trent J. Dupuy[1], M. C. Liu[2]

[1]*CfA/SAO,* [2]*IfA/Hawaii.*
9:00 AM - 6:30 PM

We present results from our infrared parallax program at the 3.6-meter Canada-France-Hawaii Telescope (CFHT) using the wide-field imager WIRCam. The large field-of-view of one WIRCam chip (10' × 10') affords a much larger number of reference stars than previous programs, with most targets having >100 reference stars. Queue service observing at CFHT also enables excellent coverage of the parallax curves for targets over a wide range of right ascensions, and excellent seeing at Mauna Kea has yielded a median FWHM of 0.6" for our observations. The resulting parallax precision we achieve has a median of 1.3 mas and ranges from 0.7–2.7 mas depending on the number of epochs obtained (median of 10 epochs obtained over 2.3 years). These parallaxes are essential for expanding the number of dynamical masses of ultracool dwarfs, particularly at the L/T transition. In addition to these benchmark ultracool binaries, we have been obtaining precise distances for young field brown dwarfs (≈10–100 Myr) and the latest type T dwarfs (T8+) discovered in recent years by the UKIDSS and CFBDS wide-field surveys.

345.26 – **Comparing Low- and High-Resolution Model Fits to T Dwarf Spectra**

Erin Boettcher[1], E. Rice[2], I. S. McLean[3], T. Barman[4], K. Cruz[5], S. Douglas[6]

[1]*Haverford College,* [2]*American Museum of Natural History, The College of Staten Island,* [3]*UCLA,* [4]*Lowell Observatory,* [5]*American Museum of Natural History, Hunter College,* [6]*Franklin and Marshall College.*
9:00 AM - 6:30 PM

Brown dwarfs provide indispensable laboratories for studying the physics and chemistry of cool atmospheres in detail, and the understanding gained is directly applicable to gas giant exoplanets. Creating quality models for brown dwarf atmospheres is dependent on developing models for which the physical parameters inferred from best-fit spectra are consistent at all resolutions and across all wavelength regimes. For a sample of T dwarfs, we have begun to test the consistency of PHOENIX models by comparing best-fit parameters for low- and high-resolution near-infrared spectra. We fit low-resolution ($\Delta\lambda \approx 4$ Å) SpeX Prism data from the NASA Infrared Telescope Facility Spectral Library and high-resolution ($\Delta\lambda \approx 0.625$ Å) Keck/NIRSPEC data from the Brown Dwarf Spectroscopic Survey with PHOENIX cond (dust-free) model spectra calculated specifically for this project. The best-fit models for the high-resolution data were found using the MPFIT model fitting routine, while the best-fit models for the low-resolution data were found using a Markov Chain Monte Carlo routine. For twelve T dwarfs, the discrepancies between the low- and high-resolution best-fit effective temperature and surface gravity parameters are discussed. The low-resolution best-fit parameters are somewhat more consistent with expectations in effective temperature and are conclusively more consistent with expectations in surface gravity.

345.27 – **A Study of Young Brown Dwarfs in the Mid Infrared**

Joseph P. Lyons[1], K. N. Allers[2], M. Herzog[2], M. C. Liu[3]

[1]*University of Massachusetts Amherst,* [2]*Bucknell University,* [3]*University of Hawai'i.*
9:00 AM - 6:30 PM

We present findings on the mid infrared colors (3-24 microns) of a sample of forty-six young(~10~100Myrs) field brown dwarfs with spectral types M thru L. The infrared data came from Spitzer's IRAC and MIPS instruments, as well as WISE's preliminary release data. When looking at SEDs we find seven of seventeen M type objects showing excesses at 12 and 24 microns likely due to a disk that is unexpected for their age. We also find that L types in general have redder near-IR colors than their field counterparts that persist up to about 5 microns. Young L-type brown dwarfs are known to have redder near-IR colors than their field counterparts. We discuss the plausibility of mechanisms causing these unusually red colors in both the near-IR and mid-IR. These mechanisms could help to understand the red color also found in the exoplanets HR8799BCD.

345.28 – **Determining Youth Indicators Among Brown Dwarfs**

Emily Lemonier[1], K. Cruz[1], V. Baldassare[2]

[1]*AMNH,* [2]*Hunter College.*
9:00 AM - 6:30 PM

We have obtained high resolution optical and near-infrared spectra of suspected young brown dwarfs from the MIKE echelle spectrograph on Magellan, the NIRSPEC spectrograph on Keck, and the PHEONIX spectrograph on Gemini-South. In this poster we present radial velocities and combine them with distances and proper motion to determine their true UVW stellar velocities, assign cluster membership, and adopt ages. If the brown dwarf stars are indeed young and cluster members as we suspect, they will be benchmark stars to calibrate other observable youth indicators among brown dwarfs.

345.29 – **Application of Mie Theory to L Dwarf Cloud Models**

Kay Hiranaka[1], K. Cruz[2], M. Marley[3]

[1]*Hunter College, Graduate Center, CUNY & American Museum of Natural History,* [2]*Hunter College, CUNY & American Museum of Natural History,* [3]*NASA Ames Research Center.*
9:00 AM - 6:30 PM

Young L dwarfs are thought to have thick clouds that make their near-IR spectra red. Their cloud properties may be similar to those of the directly imaged young Jupiters, like those orbiting HR 8799. It has been observed that de-reddened spectra of young L dwarfs look similar to those of normal, field-aged objects, suggesting that small grains are playing a large role in the scattering in L dwarf clouds. This poster describes our efforts to use Mie theory to find the combination of dust properties that best reproduces the effects seen in the spectra of young brown dwarfs and thus constrain the properties of the clouds present. A better understanding of the role of clouds in low gravity objects may help explain the thick condensate clouds observed in the very low gravity--although much cooler--directly imaged planets.

345.30 – **A Model For Pulsed Radio Cmi Emission From Ultra Cool Dwarfs**

Robert Lucien Mutel[1]

[1]*Univ. of Iowa.*
9:00 AM - 6:30 PM

Pulsed radio emission has been detected from several from rapidly rotating ultra cool dwarfs (UCD's). The pulses are short-duration, highly circularly polarized, have a pulse period approximately equal to the stellar rotation period, and a phase that depends on frequency. These characteristics can be explained by cyclotron maser instability (CMI) emission from the polar regions of a co-rotating magnetosphere that is obliquely oriented w.r.t. the star's rotation axis. I present 3-dimensional ray-tracing results for CMI-generated radiation at the local cyclotron frequency that account for all major observed features of the pulsed emission.

345.31 – **"Spectral Classes": A Mast Tool For Selecting Stars According To Their Spectral Types**

Myron Smith[1], R. W. Thompson[1], R. O. Gray[2], C. J. Corbally[3]

[1]*Computer Sciences Corp.,* [2]*Appalachian State Univ.,* [3]*Vatican Obs. Res. Grp..*
9:00 AM - 6:30 PM

As previously described in M. Smith et al. 2007AAS...211.4709S, we have constructed a spectral classification digital coding system that assigns the full spectral type, class, and spectral peculiarities for stars in an archival database or catalog. This service is also described in a IVOA Design Note. To develop this into a user-friendly tool, we have developed an interface that permits requests for lists of names of stars that have a uniform range of common spectral type properties as long as they have been observed by missions supported by MAST (Multi-Mission Archive at Space Telescope). Depending on their research goal researchers can use the list to download representative MAST-held spectra of "like stars" and/or all the MAST held spectra for them. Although this tool facilitates research on individual stars, its primary purpose is to provide a new ability to collate data for special purposes, such as construction of spectral atlases or to facilitate like star queries using VO spectral services like VOSpec and Specview. As a parallel service, the interface permits users to obtain spectral classification from the Skiff catalog. In addition, if the spectral type is known, it can be listed in retrievals following queries to the standard MAST mission data search forms.

346 – Spiral Galaxies

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

346.01 – **Cool Dust in the Outer Ring of NGC1291**

Joannah L. Hinz[1], C. W. Engelbracht[1], R. Skibba[1], J. Donovan Meyer[2], A. Crocker[3], K. Sandstrom[4], F. Walter[4], B. D. Johnson[5], KINGFISH Team

[1]*Univ. of Arizona,* [2]*Stony Brook University,* [3]*Univ. of Massachusetts,* [4]*Max-Planck-Institut fur Astronomie, Germany,* [5]*Institut d'Astrophysique de Paris, France.*
9:00 AM - 6:30 PM

We present Herschel Space Observatory images of a nearby outer ring galaxy, NGC 1291, which is part of the KINGFISH Survey. We show that the ring brightens and becomes wider at far-infrared wavelengths. The mass of cool dust in the ring dominates the total dust mass of the galaxy, and the temperature of the dust emission in the ring is cool than that of the inner galaxy. We present several possible explanations for the difference in dust temperature, including one which invokes an age spread in the main morphological features of the galaxy, with the outer ring having formed before the inner lens and bar.

346.02 – **Molecular Gas and Star Formation in Atomic Gas Dominated Regions - Results from the HERACLES Survey**

Andreas Schruba[1], A. K. Leroy[2], F. Walter[3], HERACLES team

[1]*California Institute of Technology,* [2]*National Radio Astronomy Observatory,* [3]*Max Planck Institute for Astronomy, Germany.*
9:00 AM - 6:30 PM

We perform a sensitive search for faint CO emission and study how it is related to star formation in HI-dominated regions of 45 nearby spiral and dwarf galaxies using observations of CO (HERACLES), HI (THINGS), IR & Halpha (SINGS/LVL), and UV (GALEX NGS). Constraining the molecular gas content in HI-dominated regions is a crucial measurement to distinguish the role of atomic and molecular gas in the star formation process. We apply a novel technique, leveraging HI velocity fields from THINGS and wide area coverage of HERACLES to stack CO spectra and significantly increase the sensitivity. For spiral galaxies, CO (and thus H2) is linearly related to tracers of star formation (IR, Halpha, FUV) and does not depend on gas density. Meanwhile, the H2-to-HI ratio varies by several orders of magnitude with radius and total gas surface density and thus sensitively regulates the supply of star-forming molecular gas. For dwarf galaxies, we determine sensitive upper limits on the CO luminosity both near star-forming peaks and the entire galaxy and find CO emission to be faint both in an absolute sense and normalized by B-band luminosity and star formation rate (SFR). The ratio SFR/CO increases by more than an order of magnitude toward low metallicities which likely indicates a dramatic increase in the CO-to-H2 conversion factor.

346.03 – **The IRAM Large Program HERACLES: The HERA CO-line Extragalactic Survey**

Adam K. Leroy[1], F. Walter[2], A. Schruba[3], HERACLES Collaboration

[1]*National Radio Astronomy Observatory,* [2]*Max Planck Institute for Astronomy, Germany,* [3]*California Institute of Technology.*
9:00 AM - 6:30 PM

We present the results and publicly available data products from the IRAM Large Program HERACLES (the HERA CO-Line Extragalactic Survey), which produced wide-field, sensitive maps of CO J=2-1 emission from 48 nearby galaxies. Combining HERACLES with VLA HI (mostly from THINGS), GALEX ultraviolet, and Spitzer infrared data (mostly from SINGS) we have investigated the link between gas, star formation, and local conditions. Here we highlight our results (1) estimating star formation rates in a way that takes advantage of this full suite of multiwavelength, (2) exploring the distribution of CO emission down to very low brightness using novel stacking techniques, and (3) comparing key local conditions (the dust-to-gas ratio, stellar mass surface density, and local dynamical time) to the efficiency with which stars form from molecular gas at 1-kpc resolution across our diverse sample. We also present the publicly released HERACLES data products.

346.04 – **The Connection Between Shear And Star Formation In Spiral Galaxies: Disk Star Formation Rates From 24 Micron Spitzer Imaging Data.**

Marc Seigar[1], A. Sierra[1]

[1]*University of Arkansas at Little Rock.*
9:00 AM - 6:30 PM

We test the relationship between shear and star formation in disk galaxies, using a combination of Spitzer 3.6-micron and 24-micron data. The 24-micron data is decomposed into disk and bulge components, as is the 3.6-micron data. A ratio of 24-micron to 3.6-micron data is then computed as an indicator of the specific star formation in the disk. We find that this parameter correlates well with the shear as calculated from rotation curve data.

346.05 – **Star Formation Rates in Resolved Galaxies: Near to Far Infrared Calibrations**

Yiming Li[1], A. F. Crocker[1], D. Calzetti[1], C. D. Wilson[2], R. C. Kennicutt[3], E. J. Murphy[4], KINGFISH Team

[1]*Dept. of Astronomy, University of Massachusetts, Amherst,* [2]*Department of Physics & Astronomy, McMaster University, Canada,* [3]*Institute of Astronomy, Cambridge University, United Kingdom,* [4]*Department of Physics & Astronomy, University of Wyoming.*
9:00 AM - 6:30 PM

We use the Brγ hydrogen recombination line as a reference star formation rate (SFR) to test the validity and calibration of the Herschel PACS 70, 100 and 160μm emission as a SFR indicator for HII regions in external galaxies. Brγ offers the double advantage of tracing ionizing photons directly, and being relatively insensitive to the effects of dust attenuation. For our first experiment, we use CFHT archival Brγ and Ks images of two Key Insights on Nearby Galaxies: a Far-Infrared Survey with Herschel (KINGFISH) galaxies: NGC5055 and NGC6946. We demonstrate the use of Brγ to establish the calibrations of SFR(70), SFR(100) and SFR(160) for HII regions in the two galaxies and compare the calibrations at different scales and at different wavelengths. We find that the use of combinations of the observed Hα and a fraction of each of the three far-infrared (FIR) bands applicable as a proxy of extinction corrected Hα Calibrations of FIR SFR indicators could also be established and the comparison of Calibration Coefficients (C) at different scales reveals more diffuse non-star-forming 70μm emission, as we probe star forming regions of smaller physical sizes and gives possibility on similar analysis done for 100 and 160μm with more data available. Although only crude numbers could be derived due to the limited quality of archive Brγ data, we demonstrate the power of using a consistent reference SFR indicator to calibrate the FIR SFR indicators and to analyze the calibrations at different scales and at different bands. We expect to have similar analysis, with detailed studies, done with better quality Brγ maps (observed or to be observed). The HII region luminosity functions, consistent with previous studies, using the Brγ emission line, are presented as well. This work has been supported by JPL KINGFISH grant.

346.06 – **The Tully-fisher Relation For 25,000 SDSS Galaxies As Function Of**

Environment

Philip Mocz[1], A. Green[2], M. Malacari[3], K. Glazebrook[2]

[1]*Harvard University,* [2]*Swinburne University, Australia,* [3]*University of Adeleide, Australia.*

9:00 AM - 6:30 PM

We construct Tully-Fisher relationships (TFRs) in the u, g, r, i and z bands and stellar mass TFRs (smTFRs) for a sample of 25,698 galaxies (with $0.045<z<0.085$) from the Sloan Digital Sky Survey (SDSS) and study the effects of environment on the relation. We use SDSS-measured Balmer emission line widths, v_FWHM, as a proxy for disc circular velocity, v_circ. A priori it is not clear whether we can construct accurate TFRs given the small 3" diameter of the fibres used for SDSS spectroscopic measurements. However, we show by modelling the H-alpha emission profile as observed through a 3" aperture that for galaxies at appropriate redshifts ($z>0.045$) the fibres sample enough of the disc to obtain a linear relationship between v_FWHM and v_circ, allowing us to obtain a TFR and to investigate dependence on other variables. We also develop a methodology for distinguishing between astrophysical and sample bias in the fibre TFR trends. We observe the well-known steepening of the TFR in redder bands in our sample. We divide the sample of galaxies into four equal groups using projected neighbour density (Sigma) quartiles and find no significant dependence on environment. Having demonstrated that we can construct SDSS-based TFRs is very useful for future applications because of the large sample size available.

346.07 – **A Comparison of Methods for Measuring Supermassive Black Hole Methods**

Ismaeel Ahdulla Akhlite Al-Baidhany[1], M. S. Seigar[1], P. Treuthardt[1], D. Kennefick[2], J. Kennefick[2], C. H. S. Lacy[2], B. Davis[2]

[1]*University of Arkansas at Little Rock,* [2]*University of Arkansas at Fayetteville.*

9:00 AM - 6:30 PM

In this study we compare the masses of supermassive black holes (SMBHs) in a sample of ~80 spiral galaxies estimated by applying the correlations between supermassive black hole mass (MBH) and host-galaxy bulge velocity dispersion (σ), luminosity (L; the MBH-σ and MBH-L relations), maximum rotation velocity and pitch angle relations. These measurements are used to calculate the mass of the SMBH at the center of each of these galaxies. Here all used methods provide a determination of SMBH mass. We determine pitch angles using a 2D Fourier decomposition technique, bulge luminosity using a 2-D surface brightness profile modeling routine, and take velocity dispersions and maximum rotation velocities from the literature. We determine and compare SMBH masses using each method.

346.08 – **Kinematics Of M31's Inner Spheroid Using SPLASH and PHAT Data**

Claire Dorman[1], P. Guhathakurta[1], M. A. Fardal[2], M. C. Geha[3], K. M. Howley[1], J. S. Kalirai[4], D. Lang[5], J. Cuillandre[6], J. Dalcanton[7], K. M. Gilbert[7], A. C. Seth[8], B. F. Williams[7], B. Yniguez[9]

[1]*UC Santa Cruz,* [2]*University of Massachussetts,* [3]*Yale University,* [4]*Space Telescope Science Institute,* [5]*Princeton University,* [6]*Canada-France-Hawaii Telescope,* [7]*University of Washington,* [8]*University of Utah,* [9]*UC Irvine.*

9:00 AM - 6:30 PM

Our proximity to and external view of the Andromeda galaxy (M31) make it an excellent testbed for probing the relationship between structural subcomponents (e.g., disk and spheroid) of a large spiral galaxy. The combination of large size, high metallicity, and Sersic surface brightness profile (with index n_Sersic ~ 2-4) of M31's spheroid suggest that it is unlike any subcomponent of the Milky Way. We use resolved stellar kinematics from Keck/DEIMOS spectra of 5600 red giant branch stars to disentangle M31's spheroid from its stellar disk. Kinematical evidence is presented for the northern extension of the Giant Southern Stream. We show that accounting for the stream and associated tidal debris, in addition to a locally cold stellar disk, yields a systematic rotation pattern in the spheroid. We measure the mean velocity and dispersion of the spheroid in each of five spatial bins. We detect significant rotation beyond r_proj ~ 10 kpc. This is the first time that rotation has been detected in the spheroid past r_proj ~ 1 kpc. The velocity dispersion decreases from 150 km/s at r_proj = 4 kpc to 115 km/s at r_proj = 14 kpc, consistent to 2σ with previous measurements as well as with a bulge/halo model. We also calculate the probability that a given star is a member of the spheroid and that the spheroid has a significant contribution at all radii in our sample along both the major and minor axes. Lastly, we show that the v_rot/σ more closely resembles that of a so-called "fast rotating" elliptical galaxy than of a rotationally-flattened spiral galaxy bulge, but it should be cautioned that our M31 spheroid measurements are much further out (in units of effective radius) than for the comparison samples.

This research was supported by the National Science Foundation and NASA.

346.09 – **3D Mapping Of Dusty Clouds In The Nuclear Bulge Of M31**

Hui Dong[1], Z. Li[2], D. Wang[3], K. Olsen[1], J. Dalcanton[4], A. Saha[1]

[1]*NOAO,* [2]*CfA,* [3]*University of Massachusetts, Amherst,* [4]*University of Washington.*

9:00 AM - 6:30 PM

M31 provides the closest galactic nucleus in a giant spiral galaxy, where we can study in great detail from X-ray to radio. However, the interstellar material in the circum-nuclear region of the galaxy remains poorly understand. Here, we present a map of dusty clouds in the central 4x4 arcmin square region, constructed pixel-by-pixel via fitting the spectral energy distribution over the near-IR to UV range, using the nine images from HST WFC3 and ACS: 5 bands from the Panchromatic Hubble Andromeda Treasury survey (PHAT), 3 bands from our Cycle-18 nuclear spiral mapping, and 1 band from the archive. This fitting gives both the extinction and the line-of-sight location of the clouds in the galactic bulge. The map further allows us to estimate their sizes and densities, as well as their spatial distribution. These results have strong implications for understanding the formation and destruction processes of the clouds in the circum-nuclear region of the galaxy.

346.10 – **A Study Of The Kinematics Of Stellar Sub-populations In M31's Disk And Spheroid Using PHAT And SPLASH Data**

Puragra Guhathakurta[1], C. Dorman[1], A. Seth[2], J. Dalcanton[3], K. Gilbert[3], K. Howley[4], L. C. Johnson[3], J. Kalirai[5], T. Krause[6], D. Lang[7], B. Williams[3], PHAT team, SPLASH collaboration

[1]*UC, Santa Cruz,* [2]*U of Utah,* [3]*U Washington,* [4]*LLNL,* [5]*STScI,* [6]*Castilleja School,* [7]*Princeton U.*

9:00 AM - 6:30 PM

We present a comparative study of the kinematics of different types of stars in the Andromeda galaxy (M31). Our fields of study span a range of projected radii from 2 to 15 kpc in the NE and SE quadrants of M31's disk and spheroid. The kinematical part of this study is based on radial velocity measurements of a few thousand stars obtained using the Keck II telescope and DEIMOS spectrograph as part of the SPLASH survey. The DEIMOS spectra have a spectral resolution of about 1.5 Angstrom (FWHM) and cover the wavelength range 6500-9000 Angstrom. The stellar populations part of this study - specifically, the division of stars into sub-populations - is based on high spatial resolution Hubble Space Telescope (HST) Advanced Camera for Surveys (ACS) and Wide-Field Camera 3 (WFC3) images and photometry in six filters: two ultraviolet bands (F275W and F336W), two optical bands (F475W and F814W), and two near-infrared bands (F110W and F160W). The stellar sub-populations we study include metal-rich, metal-intermediate, and metal-poor red giants, asymptotic giant branch stars, He-burning blue loop stars, massive main sequence stars, planetary nebulae, and X-ray binaries. Kinematical information allows us to measure the fraction of each sub-population that is associated with M31's disk versus its spheroid. The excellent synergy between HST and Keck provides insight into the relationship between the dynamical, star formation, and chemical enrichment histories of the structural sub-components of M31 and, by association, other large spiral galaxies.

This research was supported by the National Science Foundation, NASA, and the Science Internship Program (SIP) at UCSC.

346.11 – **The Panchromatic Hubble Andromeda Treasury: Bright UV Stars in the Bulge of M31**

Philip Rosenfield[1], L. Johnson[1], L. Girardi[2], J. J. Dalcanton[1], A. Bressan[3], D. Lang[4], B. F. Williams[1], K. M. Howley[5], P. Guhathakurta[6], Panchromatic Hubble Andromeda Treasury Survey Team

[1]*University of Washington,* [2]*Osservatorio Astronomico di Padova -- INAF, Italy,* [3]*SISSA, Italy,* [4]*Department of Astrophysical Sciences, Princeton University,* [5]*Lawrence Livermore National Laboratory,* [6]*University of California Observatories/Lick Observatory, University of California.*

9:00 AM - 6:30 PM

As part of the Panchromatic Hubble Andromeda Treasury (PHAT) multi-cycle program, we observed a $12' \times 6.5'$ area of the bulge of M31 with the WFC3/UVIS filters F275W and F336W . From these data we have assembled a sample of ~8000 UV-bright, old stars, vastly larger than previously available. We use updated Padova stellar evolutionary tracks to classify these hot stars into three classes, including Post-AGB stars (P-AGB), Post-Early AGB (PE-AGB) stars and AGB-manque stars. P-AGB stars are the end result of the AGB phase and are expected in a wide range of stellar populations, whereas PE-AGB and AGB-manque (together referred to as hot post-horizontal branch HP-HB) stars are the result of insufficient envelope masses to allow a full AGB phase, and are expected to be particularly prominent at high helium or α abundances when the mass loss on the RGB is high. Our data support previous claims that most UV-bright sources in the bulge are likely hot horizontal branch stars (EHB) and their progeny. We construct the first radial profiles of these stellar populations, and show that they are highly centrally concentrated, even more so than the integrated UV or optical light. However, we find that this UV-bright population does not dominate the total UV luminosity at any radius, as we are detecting the progeny of the EHB stars that are the likely source of the UVX. We calculate that only a few percent of MS stars in the central bulge can have gone through the HP-HB phase and that this percentage decreases strongly with distance from the center. We also find that the surface density of hot UV-bright stars has the same radial variation as that of LMXBs. We discuss age,

metallicity, and abundance variations as possible explanations for the observed radial variation in the UV-bright population.

346.12 – **Beyond the Break: Observational Evidence of Stellar Migration**

Peter Yoachim[1], R. Roškar[2], V. P. Debattista[3]

[1]*Univ. of Washington,* [2]*University of Zürich, Institute for Theoretical Physics, Switzerland,* [3]*Jeremiah Horrocks Institute, University of Central Lancashire, United Kingdom.*

9:00 AM - 6:30 PM

We use the VIRUS-P IFU spectrograph to observe 6 nearby disk galaxies. In three cases (NGC 2684, NGC 6155, and NGC 7437), we find that a downward break in the disk surface brightness profile corresponds with a change in the dominant stellar population with the interior being dominated by active star formation and the exterior having older stellar populations. This is similar to theoretical models that predict surface brightness breaks are caused by stellar migration, with the outer disk being populated from scattered old interior stars.

In three more cases (IC 1132, NGC 4904, and NGC 6691), we find no significant change in the stellar population as one crosses the break radius. In these galaxies, both the inner and outer disks are dominated by active star formation and younger stellar populations. While radial migration can contribute to radial profile breaks, it appears multiple mechanisms are required to explain all of our observed stellar profile breaks.

346.13 – **Water Masers in the Andromeda Galaxy: The First Step Toward Proper Motion**

Jeremiah K. Darling[1]

[1]*Univ. of Colorado, Boulder.*

9:00 AM - 6:30 PM

We present the recent discovery of water masers in the Andromeda Galaxy (M31) and describe how precise astrometry can be used to measure the proper motion of M31. The proper motions of the maser complexes will show three signatures on the sky:

(1) a bulk proper motion due to the transverse velocity of M31 on the sky, providing the unknown components of its full three-dimensional velocity,

(2) a proper rotation, which can provide a geometric distance measurement to M31, limited primarily by uncertainties in the rotation profile of M31 and peculiar maser motions, and

(3) an apparent divergence caused by the 300 km/s approach of M31 toward the observer, which can provide an independent geometric distance measurement.

These proper motion measurements will jointly address the dark matter content and future evolution of the Local Group of galaxies including whether or not the Local Group forms a bound system and whether (or when) M31 and the Milky Way will collide and merge.

This research is supported by NSF grant AST-1109078.

346.14 – **Warp Characteristics of Spiral Galaxies in the Virgo Cluster**

Hyun-Jin Bae[1], A. Chung[1], S. S. Kim[2], G. I. G. Jozsa[3], S. Yoon[1]

[1]*Yonsei University, Korea, Republic of,* [2]*Kyung Hee University, Korea, Republic of,* [3]*ASTRON, Netherlands.*

9:00 AM - 6:30 PM

We present the warp characteristics of 22 spiral galaxies in the Virgo cluster based on their VLA HI datacubes with unprecedented precision. The tilted-ring modeling method is used to examine kinematic properties of the HI disks including the inclination and position angle. The main results are as follows. First, 17 out of the 19 (89.5 %) successfully-modeled galaxies exhibit either weak or strong warps, indicating that the warps are very common not only galaxies in isolation but ones in dense environments. Second, the warp strength decreases with increasing dynamical mass, supporting the notion that the warps are primarily controlled by dark matter halos. Last, the warp characteristics in our sample are distinct from those of isolated galaxies, in that the warps in our sample varies a great deal in inclination, but little in position angle. This implies that in dense environments, the main driver of the disk warps is most likely the galactic tidal interaction, rather than other explanations such as the cosmic infall scenario.

346.15 – **Disk Galaxy Warp Formation via Close Encounters**

Jeonghwan Kim[1], S. Peirani[2], S. Kim[3], S. Yoon[1]

[1]*Yonsei University, Korea, Republic of,* [2]*Institut d'Astrophysique de Paris, France,* [3]*Kyung Hee University, Korea, Republic of.*

9:00 AM - 6:30 PM

Warped disks appear to be ubiquitous among spiral galaxies. We present a new scenario for the warp formation, in which galactic fly-by encounters are main drivers of the warp structure. Based on N-body simulation using a publicly available code Gadget2, we investigate morphological and kinematical structures of disk galaxies while the galaxies are undergoing fly-by encounters with adjacent dark matter halos. In this study, we find that warps can be excited by impulsive encounters and sustained for a few billion years. We also find that encounters cause the initially spherical halos to deform into intricate shape halos at the inner regions where warps are generated. Most of the warps from the simulation show inclination angles that are comparable to the observations. The creation of warps, their inclination and their lifetimes are governed primarily by the following three parameters: the impact parameter (the minimum distance between two halos), the mass ratio between two galaxies, and the incoming angle of the intruder. We discuss pros and cons about our alternative scenario in comparison with existing explanations.

346.16 – **Revisiting the Spiral Density Wave Paradigm in M51 with PAWS**

Sharon Meidt[1], E. Schinnerer[1], S. Garcia-Burillo[2], A. Hughes[1], D. Colombo[1], J. Pety[3], A. Leroy[4], K. Schuster[3], C. Kramer[5], G. Dumas[3], C. Dobbs[6], T. Thompson[7]

[1]*MPIA, Germany,* [2]*OAN, Spain,* [3]*IRAM, France,* [4]*NRAO,* [5]*IRAM, Spain,* [6]*MPE, Germany,* [7]*OSU.*

9:00 AM - 6:30 PM

The interacting Whirlpool galaxy M51 is a favorite test-bed for spiral arm density wave theories, and studies of the spiral morphology and kinematics show evidence for the offset alignment of the gaseous, young and old stellar tracers predicted by theory, as well as strong non-circular gas streaming motions. Now, the unparalleled high resolution of the PAWS (PdBI Arcsecond Whirlpool Survey, PI:Schinnerer) data, combined with exceptional multi-wavelength coverage, makes it an ideal target for revisiting the density wave picture and for examining the influence of bar and spiral instabilities on secular evolution. We present an updated view of the current dynamical state of the system, with particular emphasis on GMC scales. Gas kinematics at these scales--available for the first time in a spiral outside the Local Group--are a critical tool for assessing the influence of spiral arms on the organization of the ISM. To interpret the role of pressure and shear on GMC formation and evolution, we combine these data with a 2D map of spiral arm torques newly derived from the stellar mass distribution mapped with S4G 3.6 and 4.5 μm images. We also compare gas inflow and star formation rates throughout the disk, assembling a view of the spatial-dependence of consumption timescales for the current gas reservoir.

346.17 – **Molecular Gas and Giant Molecular Clouds in M51: Insights from PAWS**

Annie Hughes[1], D. Colombo[1], E. Schinnerer[1], J. Pety[2], S. Meidt[1], A. Leroy[3], C. Dobbs[4], G. Dumas[2], S. Garcia-Burillo[5], C. Kramer[6], K. Schuster[2], T. Thompson[7]

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9:00 AM - 6:30 PM

The Plateau de Bure Arcsecond Whirlpool Survey (PAWS) has imaged the CO emission at high resolution (~40pc) across the central ~8 kpc of the iconic massive spiral galaxy M51. In this contribution, we present first results from PAWS that further our understanding of the physical state of the molecular gas, the formation of giant molecular clouds (GMCs) and the capacity of the molecular ISM to form stars within different galactic environments. More than half of the CO emission detected by PAWS arises from an extended low surface brightness component that is unlikely to originate from gas that is self-gravitating. After excluding this component, we find that the fraction of the bright CO emission that can be decomposed into cloud-like structures increases in the interarm region. While GMCs in the spiral arms of M51 have similar physical properties as GMCs between the arms, we show that M51 clouds differ significantly from the properties of GMC populations in nearby dwarf galaxies, where cloud-like structures account for a much larger fraction of their host galaxy's total CO luminosity. We present a comparison between GMC mass spectra and the probability distribution functions (PDFs) of CO brightness on different spatial scales for environments within M51, M33 and the LMC, and suggest that PDFs may be a useful benchmark for models that aim to reproduce the molecular gas content of galactic disks. Our analysis suggests that the morphology of the interstellar medium, as well as metallicity, is important for explaining observed variations in the ratio between the CO luminosity and global star formation rate for different galaxy types.

346.18 – **The Apparent Counter-Winding Bar-Spiral Hybrid of NGC 3124**

Patrick M. Treuthardt[1], M. Seigar[1]

[1]*University of Arkansas at Little Rock.*

9:00 AM - 6:30 PM

The bar in the unusual SB(r)bc galaxy of NGC 3124 appears to be a very open spiral pattern winding in the opposite sense of the outer spiral arms. We show preliminary results of our photometric analysis of high resolution B, V, R, and I-band images from the Carnegie-Irvine Galaxy Survey. We also show preliminary results of our attempts to recreate the observed morphology with inelastically colliding test particle simulations.

346.19 – **Using Dwarf Spheroidal Satellites as Probes of Galaxy Properties**

Abrar Choudhury[1], P. Guhathakurta[2], K. M. Gilbert[3], R. L. Beaton[4], E. J. Tollerud[5], SPLASH collaboration

[1]*Bellarmine College Preparatory,* [2]*University of California, Santa Cruz,* [3]*University of Washington,* [4]*University of Virginia,* [5]*University of California, Irvine.*
9:00 AM - 6:30 PM

We present a Keck/DEIMOS spectroscopic study of fifteen dwarf spheroidal (dSph) satellites of the Andromeda galaxy. Our aim is to understand the properties of both the dSphs and Andromeda. Previously, detailed spectroscopic studies were carried out on six of these dSphs using smaller data sets, and limited spectroscopic studies were carried out on the remaining nine. The data sets analyzed in this research include more stars and higher quality data than those of previous studies. In order to accurately study the dSphs, we have developed a method that uses the stars' velocities, metallicities, and projected distances from the center of each dSph to separate members from non-members of the dSphs. The resulting samples are expected to have a low fraction of contamination by non-members, which makes this method critical for all future studies of Andromeda dSphs. We calculate the mean radial velocities and velocity dispersions of the dSphs, and the new dSph velocity measurements are used to estimate Andromeda's dynamical mass. This mass estimate is more accurate than previous ones because it uses more dynamical tracers. The dSph-based mass estimate is corroborated by a different mass estimate based on the kinematics of Andromeda's field halo stars. This is the first time the mass of Andromeda has been calculated using its halo stars. Future steps will include calculating the dark matter content of the dSphs and comparing their chemical abundances to those of Andromeda's halo, which is made up of former dSphs.

This research was supported by the Science Internship Program (SIP) at UCSC and the National Science Foundation.

346.20 – **On the Neutral Hydrogen Filament Between M31 and M33**

Felix J. Lockman[1], N. Free[2], J. C. Shields[2]

[1]*NRAO,* [2]*Ohio University.*
9:00 AM - 6:30 PM

In 2004, Braun & Thilker (B&T) reported the detection of extremely faint 21cm HI emission at the level log10(NH)=17.0 that formed a partial bridge about 200 kpc in extent between M31 and M33. This has been interpreted as the neutral component of a WHIM filament, or the remnant of a past encounter between the two galaxies. B&T used data from the Westerbork Synthesis Radio Telescope, operated as an array of single dishes, to obtain the necessary sensitivity, but at the expense of angular resolution (~45'). Subsequently, Putman et al (2009) have questioned the existence of this filament, noting its absence from the immediate vicinity of M33 at the level log10(NH)~18 in data from Arecibo. We have reobserved much of the region between M31 and M33 using the Green Bank Telescope (GBT) at 9' resolution, with a 5-sigma sensitivity limit of log10(NHI)~18.0 and a few much deeper pointings. We detect HI lines consistent with the B&T results. In two locations the emission appears at log(NHI)>18.3, suggesting clumping in the otherwise diffuse gas. We estimate the mass of HI in the bridge, and show examples of the GBT's freedom from instrumental effects down to detection levels of log(NHI)~17.0. The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under a cooperative agreement by Associated Universities, Inc.

346.21 – **Constraining the Mass of NGC 4258 with Satellite Galaxies**

Meghin Spencer[1], P. Yoachim[1], S. Loebman[1]

[1]*University of Washington.*
9:00 AM - 6:30 PM

We combine spectroscopic observations from the APO 3.5-meter telescope with SDSS spectra to conduct a survey of satellite galaxies around the nearby spiral NGC 4258. Of the 35 observed objects, 20 appear to be members of the system. Using the projected line-of-sight velocities of the satellite galaxies and a Jeans equation approximation, we constrain the total mass of NGC 4258 to within 50%. Further observations are expected to yield around 20 more satellite velocity measurements.

346.22 – **A Study of Tidal Streams in the Via Lactea II Simulation**

Anirudh Suvarna[1], V. Rashkov[2], P. GuhaThakurta[2]

[1]*Monta Vista High School,* [2]*UC Santa Cruz.*
9:00 AM - 6:30 PM

We follow the development of tidal streams in Via Lactea II, an N-body simulation of the formation of the dark matter halo of a large spiral galaxy. A tidal stream is the remnant of a dwarf satellite galaxy disrupted by differential gravitational forces, depositing a trail of stars within the main galactic halo. Tidal streams link the development of the progenitor satellites to the virialized halo of the main galaxy. This study is more extensive than previous studies of tidal streams in simulated galactic halos because we analyze a high-resolution numerical model. We find trends in the lengths and velocity dispersions (σ) of these streams. As the streams disperse over time, their length increases. Streams originating from the most massive satellites, which interact most strongly through gravity with the main halo, approach full extent 2-3 Gyr after in-fall. Velocity dispersion also increases over time, as the stream is heated up and its stars are virialized into the main halo, with the upper range of velocity dispersions of some streams approaching that of the main halo, ~200 km/s. We also discuss further work to obtain improved measures of stream length, as well as the potential of this study, a unique and extensive analysis of a single computer simulation, to provide answers about the development of tidal streams and the evolution of their properties, and to set the path for interpretation of the multitude of data to be collected by planned and future telescopes.

This research was supported by the Science Internship Program (SIP) at UCSC and the National Science Foundation.

346.23 – **Ultraviolet Extinction in Backlit Galaxies - from Galaxy Zoo to GALEX**

William C. Keel[1], A. Manning[1], B. W. Holwerda[2], C. Lintott[3], K. Schawinski[4], Galaxy Zoo team

[1]*Univ. of Alabama,* [2]*ESA/ESTEC, Netherlands,* [3]*Oxford Univ., United Kingdom,* [4]*Yale Univ.*.
9:00 AM - 6:30 PM

We examine the ultraviolet extinction of galaxies on large scales, combining optical and GALEX UV data on backlit galaxies (most found in the Galaxy Zoo citizen-science project). We analyze the images

in matching ways, modelling both foreground and background galaxies by symmetry or elliptical isophote families as appropriate, and using the

non-overlapping regions of the galaxies to estimate errors in the derived transmission

$T=e^{-\tau}$. Spirals appear less symmetric in the UV, as star-forming regions become more dominant, so that our most reliable results are mean values across multiple regions and multiple galaxies. Our mean effective extinction curve is dominated by the contribution of luminous spirals,and shows a fairly flat ~gray" extinction law into the ultraviolet. For example, the median of τ_{NUV}/τ_B in spiral arms is only 1.3. Along with previous high-resolution HST studies of a few nearby backlit galaxies, this suggests that on kpc scales the effective extinction is dominated by the

dust clumping rather than the intrinsic reddening law. This implies that extrapolation of local properties to short wavelengths, a step toward the

history of dust in galaxies through comparison of local properties with a similar analysis in deep HST fields, can be done without introducing much

additional error. This work was supported by NASA Astrophysics Data Analysis Program grant NNX10AD54G.

346.24 – **The WSRT HALOGAS Survey**

George H. Heald[1], HALOGAS Team

[1]*ASTRON, Netherlands.*
9:00 AM - 6:30 PM

We present the status of, and early results from, the WSRT HALOGAS (Hydrogen Accretion in LOcal GAlaxieS) survey. This is the first systematic investigation of cold gas accretion in nearby spiral galaxies to date. It consists of deep (120 hours) WSRT observations of 20 edge-on and moderately-inclined nearby galaxies. Using these data

we are able to detect neutral hydrogen down to a column density of about 10^{19} cm^{-2}, and characterize the faint extra-planar and anomalous-velocity neutral gas with excellent spatial and velocity resolution. HALOGAS data also allow us to study the disk structure and dynamics in unprecedented detail for a sample of this size.

Observations carried out so far show a variety of HI properties, ranging from accretion of (and interaction with) satellite galaxies to filaments possibly caused by star formation in the disk. The detected amount of anomalous gas indicative of accretion episodes varies significantly from galaxy to galaxy. We illustrate the range of extraplanar HI features detected in the HALOGAS sample, and compare with complementary deep optical observations which have been obtained at the INT (the HALOSTARS project).

Companion posters present detailed modeling of some of the observed galaxies, and optical spectroscopic observations which complement our 21 cm data.

346.25 – **HI Streams And Spurs In HALOGAS Observations Of NGC 5055**

Maria Patterson[1], R. Walterbos[1], G. Heald[2], G. Jozsa[2], G. Gentile[3], D. Thilker[4], HALOGAS Team

[1]*New Mexico State University,* [2]*Netherlands Institute for Radio Astronomy (ASTRON), Netherlands,* [3]*Universiteit Gent, Belgium,* [4]*Johns Hopkins University.*
9:00 AM - 6:30 PM

We present the results of a tilted-ring analysis of the HI in the nearby galaxy NGC 5055 (M63) from deep observations of the Westerbork Hydrogen Accretion in LOcal GAlaxieS (HALOGAS) survey. NGC 5055 is a moderately-inclined SAbc galaxy with a large pronounced warp of the extended gaseous disk. The HALOGAS observations reveal extended emission in the form of faint HI spurs and streams in the galaxy outskirts, which were undetected in previous data. We compare these features with stellar streams seen in recent deep optical imaging and with extended UV emission from GALEX. We also characterize anomalous velocity "beard" gas in the inner region of the galaxy, which suggests a lagging halo component that may be confined to the optical star forming disk.

RW acknowledges support from NSF grant AST-0908126 and from a grant from Research Corporation for the Advancement of Science.

346.26 – **Ionized Gas Velocities for Edge-on HALOGAS Galaxies**

Catharine J. Wu[1], R. Walterbos[1], R. Rand[2], G. Heald[3], HALOGAS Team

[1]*New Mexico State University,* [2]*University of New Mexico,* [3]*ASTRON, Netherlands.*

9:00 AM - 6:30 PM

Several galaxies show decreasing rotational velocities of neutral and ionized hydrogen gas with increasing height above the disk. This is likely due to a combination of outflow from galactic fountains and infall from the IGM or satellite accretion. The degree to which each component contributes affects the rotational velocity gradient of the gas and has implications for halo formation and evolution. We present results from optical observations and modeling of the ionized extra-planar gas in NGC 4244, NGC 891, and NGC 4565, three edge-on galaxies from the HALOGAS (Hydrogen Accretion in LOcal GAlaxieS) sample. HALOGAS is a WSRT deep HI survey studying cold gas accretion in the local universe. Our 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. We compare our results to the HI velocity data and show that the neutral and ionized gas exhibit similar kinematic characteristics.

RW acknowledges support from NSF grant AST-0908126 and from a grant from Research Corporation for the Advancement of Science.

346.27 – **HALOGAS: Observations and Modeling of the Nearby Edge-on Spiral Galaxy NGC 4565**

Laura Zschaechner[1], R. Rand[1], G. Heald[2], HALOGAS Team

[1]*University of New Mexico,* [2]*ASTRON, Netherlands.*

9:00 AM - 6:30 PM

We present models of the distribution and kinematics of HI in NGC 4565, a nearby spiral galaxy observed as part of the Westerbork Hydrogen Accretion in LOcal GAlaxieS (HALOGAS) survey. These models focus on the potential existence of extraplanar gas in the form of a halo as well as the presence of a negative gradient in rotational velocity upward from the plane of the disk (a lag). Insight concerning such information helps to better understand the prevalence as well as origins of halos in spiral galaxies, specifically whether they are a result of outflow from the disk, accretion from external sources, or a combination of the two. The modeling process utilizes a recently developed semi-automated Tilted Ring Fitting Code (TiRiFiC), which applies a chi-square minimization. Current models indicate a thin HI layer, which flares at large radii.

346.28 – **Temperature Gradients In The X-ray Emission Of Edge-on Spirals?**

David Durke[1], E. M. Schlegel[1]

[1]*UTSA.*

9:00 AM - 6:30 PM

Diffuse X-ray emission above the plane of edge-on spiral galaxies has long been detected. The intensity distribution of that gas has been measured as well as crude measures of the temperature distribution.

Speculation centers on supernovae and star clusters as the sources for the energy that propels that material out of the plane. We describe here an exercise to investigate whether star clusters specifically impact this diffuse emission using several edge-on spirals observed with the Chandra X-ray Observatory.

346.29 – **X-ray Properties Across the Spiral Morphology**

Casey E. Barker[1], C. Fuse[1]

[1]*Rollins College.*

9:00 AM - 6:30 PM

In an effort to understand the evolution of morphological features spanning Sa to Sd galaxies, we have performed an analysis of 12 spiral galaxies in the Chandra X-Ray Observatory archives. While galaxies with spiral morphology display the presence of a galactic disk and arms, the variation in these and other features from early- to late-type spirals may hold information into the formation and evolution of spiral galaxies.

We have analyzed both the diffuse gas emission of the galaxies as well as their associated point source populations. The properties of the X-ray emitting populations will be discussed. Correlations highlighting the separation in spiral morphology as well as relations that can be used to better understand spiral galaxy evolution will be presented.

346.30 – **Diffuse X-ray Emission and Star Clusters in Nearby, Face-on Spiral Galaxies**

Laura D. Vega[1], M. Moore[1], L. McMaster[1], E. M. Schlegel[1]

[1]*Univ of Texas at San Antonio.*

9:00 AM - 6:30 PM

Supernovae or star clusters are expected to heat the interstellar medium and drive material into a galaxy's halo. The X-ray emission of nearby, edge-on spirals shows diffuse emission above their midplanes. For face-on spirals, we may expect a non-uniform distribution of emission if star clusters are important sources of energy. We describe the analyses and results of a study of the diffuse emission in several nearby, face-on spiral galaxies.

346.31 – **X-ray/Optical Comparisons in M83: A Preliminary Chandra/HST Perspective**

William P. Blair[1], K. Kuntz[1], K. S. Long[2], P. P. Plucinsky[3], R. Soria[4], B. C. Whitmore[2], P. F. Winkler[5]

[1]*Johns Hopkins Univ.,* [2]*STScI,* [3]*Harvard-Smithsonian CfA,* [4]*University of Sydney, Australia,* [5]*Middlebury College.*

9:00 AM - 6:30 PM

We are obtaining 750 ks of Chandra data for the nearby face-on spiral galaxy M83 as part of a Chandra cycle 12 program (Long PI). With most of the data now in hand, we are finding several hundred X-ray point sources, many of which are embedded in significant diffuse X-ray emission. We also have an HST cycle 19 program (Blair PI) to image 5 new WFC3 fields in M83 which, with two existing fields obtained in the SM4 Early Release Science program, will provide nearly complete coverage of the optical disk. Here we report a preliminary analysis of the optical counterparts of the X-ray sources within the two existing WFC3 fields of view. We find at least 102 X-ray sources in this region. Of these, 20 are in the complex starburst nucleus and will require more detailed analysis. Of the 82 non-nuclear X-ray sources, we find 19 align with supernova remnants, while the remainder are equally split between sources that have apparent stellar counterparts and those that have no obvious optical counterparts. Finally, we find a new ultraluminous X-ray source that has turned on since 2009 August and has a faint, blue optical counterpart; images from prior to turn-on indicate a low mass companion for this source. We will report on the properties of these objects as derived from the combined data sets.

We thank NASA for support of this work through Chandra Award Nos. GO1-12115A, B, and C issued by the CXC, which is administered by SAO. PFW also acknowledges NSF grant AST-0908566.

346.32 – **Giant Molecular Clouds and Star Formation in the Non-Grand Design Spiral Galaxy NGC 6946**

David Rebolledo[1], T. Wong[1], A. Leroy[2]

[1]*University of Illinois Urbana-Champaign,* [2]*NRAO.*

9:00 AM - 6:30 PM

Although the internal physical properties of molecular clouds have been extensively studied (Solomon et al. 1987), a more detailed understanding of their origin and evolution in different types of galaxies is needed. In order to disentangle the details of this process, we performed CO(1-0) CARMA observations of the eastern part of the multi-armed galaxy NGC 6946. Although we found no evidence of an angular offset between molecular gas, atomic gas and star formation regions in our observations (Tamburro et al. 2008), we observe a clear radial progression from regions where molecular gas dominates over atomic gas (for $r \leq 2.8$ kpc) to regions where the gas becomes mainly atomic ($5.6 \text{ kpc} \leq r \leq 7.6$ kpc) when azimuthally averaged. In addition, we found that the densest concentrations of molecular gas are located on arms, particularly where they appear to intersect, which is in concordance with the predictions by simulations of the spiral galaxies with an active potential (Clarke & Gittins 2006; Dobbs & Bonnell 2008). At CO(1-0) resolution (140 pc), we were able to find CO emitting complexes with masses greater than those of typical Giant Molecular Clouds (10^5-10^6 M$\odot$). To identify GMCs individually and make a more detailed study of their physical properties, we made D array observations of CO(2-1) toward the densest concentrations of gas, achieving a resolution similar to GMCs sizes found in other galaxies (Bolatto et al. 2008). We present first results about differences in properties of the on-arm clouds and inter-arm clouds. We found that, in general, on-arm clouds present broader line widths, are more massive and more active in star formation than inter-arm clouds. We investigated if the velocity dispersion observed in CO(1-0) emitting complexes reflects velocity differences between unresolved smaller clouds, or if it corresponds to actual internal turbulence of the gas observed.

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347 – Education & Public Outreach

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

347.01 – **Hubble Legacy Archive And The Public**

Jessica Harris[1], B. Whitmore[1], B. Eisenhamer[1], M. Bishop[1], L. Knisely[1]

[1]*STScI.*
9:00 AM - 6:30 PM

The Hubble Legacy Archive (HLA) at the Space Telescope Science Institute (STScI) hosts the Image of the Month (IOTM) Series. The HLA is a joint project of STScI, the Space Telescope European Coordinating Facility (ST-ECF), and the Canadian Astronomy Data Centre (CADC). The HLA is designed optimize science from the Hubble Space Telescope by providing online enhanced Hubble products and advanced browsing capabilities. The IOTM's are created for astronomers and the public to highlight various features within HLA, such as the "Interactive Display", "Footprint" and "Inventory" features to name a few. We have been working with the Office of Public Outreach (OPO) to create a standards based educational module for middle school to high school students of the IOTM: Rings and the Moons of Uranus. The set of Uranus activities are highlighted by a movie that displays the orbit of five of Uranus' largest satellites. We made the movie based on eight visits of Uranus from 2000-06-16 to 2000-06-18, using the PC chip on the Wide Field Planetary Camera 2 (WFPC2) and filter F850LP (proposal ID: 8680). Students will be engaged in activities that will allow them to "discover" the rings and satellites around Uranus, calculate the orbit of the satellites, and introduces students to analyze real data from Hubble.

347.02 – **Education and Outreach with the Virtual Astronomical Observatory**

Brandon L. Lawton[1], B. Eisenhamer[1], M. J. Raddick[2], B. J. Mattson[3], J. Harris[1]

[1]*STScI,* [2]*Johns Hopkins University,* [3]*NASA Goddard Space Flight Center and Adnet Systems, Inc.*.
9:00 AM - 6:30 PM

The Virtual Observatory (VO) is an international effort to bring a large-scale electronic integration of astronomy data, tools, and services to the global community. The Virtual Astronomical Observatory (VAO) is the U.S. NSF- and NASA-funded VO effort that seeks to put efficient astronomical tools in the hands of U.S. astronomers, students, educators, and public outreach leaders. These tools will make use of data collected by the multitude of ground- and space-based missions over the previous decades. Many future missions will also be incorporated into the VAO tools when they launch. The Education and Public Outreach (E/PO) program for the VAO is led by the Space Telescope Science Institute in collaboration with the HEASARC E/PO program and Johns Hopkins University. VAO E/PO efforts seek to bring technology, real-world astronomical data, and the story of the development and infrastructure of the VAO to the general public, formal education, and informal education communities. Our E/PO efforts will be structured to provide uniform access to VAO information, enabling educational opportunities across multiple wavelengths and time-series data sets. The VAO team recognizes that many VO programs have built powerful tools for E/PO purposes, such as Microsoft's World Wide Telescope, SDSS Sky Server, Aladin, and a multitude of citizen-science tools available from Zooniverse. We are building partnerships with Microsoft, Zooniverse, and NASA's Night Sky Network to leverage the communities and tools that already exist to meet the needs of our audiences. Our formal education program is standards-based and aims to give teachers the tools to use real astronomical data to teach the STEM subjects. To determine which tools the VAO will incorporate into the formal education program, needs assessments will be conducted with educators across the U.S.

347.03 – **Astropix: Everyone's New Portal to the Universe of Astronomical Imagery**

Robert L. Hurt[1], G. K. Squires[1], J. Llamas[1], C. Rosenthal[2], C. S. Brinkworth[1]

[1]*Caltech,* [2]*Port 49.*
9:00 AM - 6:30 PM

Astropix is a new online repository for astronomical imagery that is now available for everyone to use. Currently in a beta development state, Astropix provides powerful ways to browse, search, and download images, diagrams, artwork, and photographs from many astronomical missions. The site is built around the Astronomical Visualization Metadata (AVM) standard developed by the Virtual Astronomy Multimedia Project (VAMP) that captures all the key descriptive information for a public image, including color representations and astronomical and sky coordinates. Existing image galleries containing AVM-tagged images can easily supply them to Astropix, which downloads them, extracts the metadata into its database, and generates versions of the images at a variety of common sizes. Visitors to Astropix can search the database using simple free-text queries, or use a structured search (similar to "Smart Playlists" found in iTunes, for example). The Astropix archive also features an Xquery-based method for posting http queries and retrieving XML lists of matching imagery, allowing for scripted access to the site. Current assets include imagery from Spitzer, Chandra, ESO, Galex, Herschel, Hubble, Spitzer, and WISE, with more on the way. Website: astropix.ipac.caltech.edu

347.04 – **Combining Social Media with Innovative Ways of Communicating about the James Webb Space Telescope**

Margaret Masetti[1]

[1]*Adnet.*
9:00 AM - 6:30 PM

In keeping with the cutting-edge nature of the James Webb Space Telescope, NASA is using a variety of social and interactive media to engage the public. While we do have a regularly updated static website, we are now also using various interactives (like Flash games and a 3D Tour of the spacecraft) to better explain what the Webb telescope is and how it works. To encourage future generations, we are a partner in an educational engineering design challenge which makes use of a virtual Second Life-like world. Additionally, the public can now watch Webb come together before their eyes by accessing our live webcam, which shows telescope hardware being built in our cleanroom.

We are working to make Webb as much of a part of pop culture as the Hubble Space Telescope is. We facilitated the filming of a "Late Night with Jimmy Fallon" segment (called "Hubble Gotchu") featuring Webb and Webb scientists at NASA's Goddard Space Flight Center. A visit to the highly rated sitcom "The Big Bang Theory" resulted in Webb lithos, magnets, posters, a scale model, and more being regularly featured on the set of the show.

The most important aspect to creating interesting ways to engage the public is having the ability to communicate and form relationships with as many people as possible. To that end, we are using tools like blogs (e.g., NASA Blueshift) and popular social media (Facebook, Twitter, YouTube, and Flickr) to reach out to as many people as we can and to enable them to share and spread the content we provide.

347.05 – **Space Culture: Innovative Cultural Approaches To Public Engagement With Astronomy, Space Science And Astronautics**

Roger F. Malina[1]

[1]*University of Texas, Dallas.*
9:00 AM - 6:30 PM

In recent years a number of cultural organizations have established ongoing programs of public engagement with astronomy, space science and astronautics. Many involve elements of citizen science initiatives, artists' residencies in scientific laboratories and agencies, art and science festivals, and social network projects as well as more traditional exhibition venues. Recognizing these programs several agencies and organizations have established mechanisms for facilitating public engagement with astronomy and space science through cultural activities. The International Astronautics Federation has established an Technical Activities Committee for the Cultural Utilization of Space. Over the past year the NSF and NEA have organized disciplinary workshops to develop recommendations relating to art-science interaction and community building efforts. Rationales for encouraging public engagement via cultural projects range from theory of creativity, innovation and invention to cultural appropriation in the context of 'socially robust science' as advocated by Helga Nowotny of the European Research Council. Public engagement with science, as opposed to science education and outreach initiatives, require different approaches. Just as organizations have employed education professionals to lead education activities, so they must employ cultural professionals if they wish to develop public engagement projects via arts and culture. One outcome of the NSF and NEA workshops has been development of a rationale for converting STEM to STEAM by including the arts in STEM methodologies, particularly for K-12 where students can access science via arts and cultural contexts. Often these require new kinds of informal education approaches that exploit locative media, gaming platforms, artists projects and citizen science. Incorporating astronomy and space science content in art and cultural projects requires new skills in 'cultural translation' and 'trans-mediation' and new kinds of metrics for impact. Astronomy because of its strong networks of amateur scientists is in a good position to develop innovative public engagement via the arts and culture.

347.06 – **A Tale of Two Sites: Planning Ahead for August 2017**

Jennifer L. Bartlett[1], S. Bell[2]

[1]*US Naval Observatory,* [2]*HM Nautical Almanac Office, United Kingdom.*
9:00 AM - 6:30 PM

On August 21, 2017, most of the United States will experience a partial solar eclipse with a total solar eclipse visible from a narrow band, approximately 73 mi (118 km) wide, crossing twelve states. The Shawnee National Forest, Illinois falls within this favored region but Austin, Texas does not. While both locations lie along the April 8, 2024, path of totality, the Forest is still better positioned.

On average, three solar eclipse tracks race across the globe every two years; in rare years, as many as five solar eclipses, including partial ones, can occur. Because each individual track covers less than 1% of the Earth's surface, an average of 375 years lapse between total solar eclipses at a particular site.

In 2017, the longest duration of totality for the eclipse will darken the Shawnee National Forest (37°34.5' N, 89°7.3' W) for 2 min. 44 sec. In 2024, totality will last 4 min. 13 sec. over the Forest. Although July 7, 1442, was the last total solar eclipse here, an annular solar eclipse was visible in 1865.

In 2017, Austin will only experience a partial eclipse with ~65% of the Sun obscured. In 2024, totality will darken the state capital for 1 min. 48 sec. The last total solar eclipse here occurred on May 26, 1397, which was immediately preceded by another on

January 21, 1395. More recently, two annular solar eclipses were visible during the 20th century.

The August and April weather at both sites is generally favorable; while clouds and rain

are possible, neither is a significant threat.

What your outreach program will see and do during these eclipses depends heavily on where you are, or can go. For those impatiently awaiting their next eclipse fix, a partially eclipsed sun will set over both sites on May 20, 2012.

347.07 – **Dark Skies, Bright Kids! Year 3**

David G. Whelan[1], K. E. Johnson[1], L. D. Barcos-Munoz[1], R. L. Beaton[1], J. Borish[1], J. F. Corby[1], G. Dorsey[1], N. E. Gugliucci[1], B. J. Prager[1], P. A. Ries[1], C. E. Romero[1], K. R. Sokal[1], X. Tang[1], L. M. Walker[1], A. J. Yang[1], G. Zasowski[1]

[1]*University of Virginia.*

9:00 AM - 6:30 PM

Dark Skies, Bright Kids! (DSBK) is a program that brings astronomy education to elementary schools throughout central Virginia. In a relaxed, out-of-classroom atmosphere, we are able to foster the innate curiosity that young students have about science and the world around them. We target schools that are under-served due to their rural locale or special needs students, demonstrating that science is a fun and creative process to a segment of the population that might not otherwise be exposed to astronomy. Families are included in the learning experience during semi-annual `star parties'.

Since last January, we have expanded the breadth and depth of our educational capabilities. We have developed new programs for use in our digital planetarium. We held the first Central Virginia Star Party, providing an atmosphere where local children from multiple schools were able to share their love for astronomy. Local government and University officials were also invited so that they could experience our focused science outreach. Most recently, we have become part of Ivy Creek School's Club Day activities, bringing our program to a new segment of the elementary school system in Albemarle County: those that have `low-incidence' disabilities, requiring special attention.

We continue to develop a curriculum for after-school programs that functions as either a series of one-time activities or several months of focused outreach at one school. Many of these activities are provided on our website, http://www.astro.virginia.edu/dsbk/, for the wider astronomical community, including the new planetarium work. We have extended our book project to include two bilingual astronomy books called `Snapshots of the Universe,' one in Spanish and English, the other in French and English. These books introduce young people to some of the many wonders of the Universe through art and captions developed by DSBK volunteers.

347.08 – **Bringing the Universe to the Valley of the Sun: Astronomy Outreach at Arizona State University**

Teresa Ashcraft[1], K. A. Knierman[1], W. L. Taylor[1], M. J. Rutkowski[1]

[1]*Arizona State University.*

9:00 AM - 6:30 PM

The focal point of astronomy outreach at ASU is Astronomy Open House, which has run for more than 3 decades. It is a free event for the local community and provides an opportunity for night sky viewings with telescopes, interactions with scientist, and discussion of contemporary topics. Typically each Open House will also offer a planetarium show, activities for kids, and displays on meteorites, the Moon, and geology. During the 2010-2011 academic year approximately 900 people attended the 6 Open Houses. This was a record attendance and was in part due to targeted advertisement to K-12 student groups. To accommodate this growth we recruited additional undergraduate student volunteers, including those from both science and non-science academic backgrounds. We present here a summary of traditional Open House activities and new partnerships developed as a result of the increased volunteer pool.

Through Open House we were able to partner with other programs at ASU and in the Phoenix area and the expanded community presence developed into new events at local schools and museums (e.g., Arizona Science Center, Phoenix Zoo). Additionally, in conjunction with the International Year of Astronomy, we hosted two events for local, traditionally under-served students in which the students learned about Galileo and built their own Galileoscopes for free. In June 2011, we visited the Tsaile Public School on the Navajo Reservation to present a series of hands-on astronomy activities including a guided program inside a portable STARLAB planetarium to over 60 Navajo students.

T. Ashcraft is supported by an Arizona NASA Space Grant Fellowship. Open House is partially supported by ASU USG. Funding for Galileoscopes provided by ASU GPSA. NASA Summer of Innovation program supports events in Tsaile, AZ.

347.09 – **Alternative Mounting Systems for the Galileoscope**

Christine Welling[1], S. Pompea[2], R. Sparks[2]

[1]*Dickinson College,* [2]*National Optical Astronomy Observatory.*

9:00 AM - 6:30 PM

The Galileoscope is a kit telescope produced for the International Year of Astronomy (IYA) in 2009. As an educational tool, it has been distributed across the world. In order to successfully observe with the Galileoscope, it must be steadied in some way. The preferred method for stabilizing the Galileoscope is to use a tripod. However, this is not always possible, and other stabilization methods are needed. Alternative systems were designed to be constructable worldwide, and cost less than $5 to build. Seventeen alternative mounting systems were built and tested. Comparisons were made based on price to build, ease of construction, ease of use, and whether the system would remain pointed. This research 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 and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

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348 – Variable Stars Cataclysmic Variables and Friends

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

348.01 – **Science Literacy and Research: Making Connections Using Kepler Data**

Stacy DeVeau[1], J. Blackwell[2], D. Edwards[3], D. Ciardi[4], S. Howell[5]

[1]*Arizona NASA Educator Resource Center,* [2]*Phillips Exeter Academy,* [3]*Sherando High School,* [4]*California Institute of Technology,* [5]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

Results of and future plans for education-related components related to educator participation in the NASA/IPAC 2011 Teacher Archive Research Program (NITARP) are presented. NITARP engages both formal and informal educators in conducting authentic science research utilizing publicly available Kepler Mission data sets under the direction of scientists. This team's research entailed the analysis of stellar light curves, comparing periodicity and temperature from a sample of 250 known variable stars, to determine their characteristics using light curves, power spectra, and phased-plot diagrams. Participating educators shared their research experiences with students, educators, and the public in a variety of ways. Additionally, students were directly involved in the research project, providing additional insights into how science research is conducted. Education activities related to the science research are presented. This program provides educators, students, and the public at large, insight into the world of authentic science research while providing avenues to support science education. Linking the learning of science to the doing of science promotes true science literacy of students and the public. An understanding of the nature of science is vital to promoting the science literacy of civilization.

348.02 – **An Analysis of Known Variable Stars in the Kepler Field**

Nicholas J. Jimenez[1], K. J. Mighell[2]

[1]*Alfred University,* [2]*National Optical Astronomy Observatory.*

9:00 AM - 6:30 PM

Using the catalog of the All-Sky American Survey (ASAS) variable stars in the Kepler Field, we analyzed Kepler light curves from quarters 0, 1, and 2 using the NASA Star and Exoplanet Database (NStED) periodogram service and determined periods and amplitudes for the 777 variables we could access. The ASAS periods agree very well to the periods determined from the Kepler data except for semiregular variables. This is due to roughly a week-long interval between ASAS observations. With a higher observing frequency, these stars are much better characterized. We investigated the quality of the NStED service period determinations by comparing periods of the ASAS eclipsing binaries to the periods determined for them by Slawson et al. We determined that NStED determines similar periods to Slawson et al. for well-defined eclipsing binaries with sharply peaked periodograms, but when the main peak of the periodogram is broad there is greater uncertainty in the measurements. We also present an analysis of red giants that exhibit solar-like oscillations from the data set of Hekker et al. and compare their amplitudes (as measured from the Kepler light curves) to the strongly variable red giants in the ASAS data set. We find that variable red giants must be quiet in order to sustain solar-like oscillations.

Jimenez 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 and the Department of Defense ASSURE program through Scientific Program Order No. 13 (AST-0754223) of the Cooperative Agreement No. AST-0132798 between the Association of Universities for Research in Astronomy (AURA) and the NSF.

348.03 – **Spectral Variations of RV Tauri and Semi-Regular Variables Observed with Kepler**

Donald K. Walter[1], S. B. Howell[2], J. L. Cash[1]

[1]*South Carolina State University,* [2]*NASA Ames Research Center.*

9:00 AM - 6:30 PM

We present ground-based spectra of RV Tauri and Semi-Regular variables taken simultaneously with our Cycle 2 Kepler observations of these objects. Our data set

includes the Kepler light curves and spectra taken with the KPNO Coude Feed telescope and, for the fainter objects, the 4-meter Mayall telescope. Our spectral observations cover the region from 3700-5100 angstroms and 6400-9000 angstroms. We have spaced our ground-based observing runs out over a period of 1.5 years to include the twelve months covered by our Cycle 2 Kepler observations. Variations in the continuum, absorption lines and emission features in the spectra of these objects are discussed and compared to their simultaneously observed photometric variations acquired by Kepler. Support for this work is provided by the NSF PAARE program under award AST-0750814 and by NASA under award NNX11AB82G.

348.04 – **Pulsating B Stars observed by Kepler**

Bernard J. McNamara[1], J. Jackiewicz[1], J. McKeever[1], J. McAteer[1], L. Boucheron[1], H. Cao[1], D. Voelz[1], K. DeGrave[1], M. Kirk[1], G. Taylor[1], A. Al-Ghraibah[1], A. Pevtsov[1], B. Calabro[1], Y. Hao[1]

[1]New Mexico State Univ..

9:00 AM - 6:30 PM

In a prior investigation using Kepler data, Balona et al. (2011) found that the measured frequency spectra of B stars differed from those obtained using ground-based observations. The low amplitude frequency spectra of these stars are quantified by analyzing a larger number of B stars. These stars are then categorized using the designations adopted in the Balona et al. study. Most of the frequencies we measure are too small to be detected using conventional ground-based observations. They are probably associated with higher order spherical harmonic modes. A plan to determine the *l* values of the larger amplitude B star frequencies is presented.

348.05 – **Unusual Pulsation Properties of Red Giant Branch Stars in Kepler**

Jean McKeever[1], J. Jackiewicz[1], B. McNamara[1], J. McAteer[1], L. Boucheron[1], H. Cao[1], M. Kirk[1], K. Degrave[1]

[1]New Mexico State University.

9:00 AM - 6:30 PM

We present our preliminary findings on analysis of Kepler lightcurves for 55 stars near the top of the red giant branch (RGB). Most stars show single strong peaks at low frequencies in their power spectra (slowly pulsating with periods on the order of days to weeks). Other stars show more complex pulsations with multiple periods and a few are likely to be in binary systems. An analysis of the population as a whole will be presented.

348.06 – **Understanding Stellar Periodicity with Kepler Quarter 1 Data**

Christine Burns[1], D. R. Ciardi[2], S. B. Howell[3], J. A. Blackwell[4], B. L. Rachford[1], S. N. DeVeau[1], D. L. Costache[1], D. Edwards[5], D. S. Stiles[1], R. C. Esplin[1]

[1]Embry-Riddle Aeronautical University, [2]NASA Exoplanet Science Institute/Caltech, [3]NASA Ames Research Center, [4]Phillips Exeter Academy, [5]Earth Science/Environmental Science/Astronomy Teacher.

9:00 AM - 6:30 PM

The NASA/IPAC 2011 Teacher Archive Research Program (NITARP) research team utilizing publicly available Kepler Mission data sets characterized the variability of 250 main sequence stars from the early release quarter one Kepler data release. Our goal was to investigate the sources of stellar variability as a function of stellar temperature (4000 - 10000 K). By utilizing a Lomb-Scargle periodogram analysis and a visual inspection of the phased light curves, we investigated the presence of periodicity in each of these stars. We explored the percentage of variable stars that are periodic and the associated distribution of periods as a function of stellar temperature.

348.07 – **Searching For Stellar X-ray Cycles With XMM-Newton**

John Hoffman[1], H. Guenther[2], N. Wright[2]

[1]University of Illinois at Urbana/Champaign, [2]Harvard-Smithsonian Center for Astrophysics.

9:00 AM - 6:30 PM

Stellar activity cycles are known to be a widespread phenomenon amongst moderately active stars due to long term monitoring of chromospheric Ca II H and K emission lines by O.C. Wilson and others. Whether or not similar periodicities exist in the X-ray spectra of most solar-type stars, however, is currently unknown. Apart from our sun, only a handful of stellar X-ray cycles have been observed (61 Cygni (A and possibly B), HD 81809 and Centauri B). We seek to improve our perspective of stellar X-ray cycles by surveying a large population of serendipitous stellar sources in XMM-Newton fields which have been observed frequently over long timescales of ~10 years. We present our analysis of 46 sources (with 6 G and K stars) from 8 fields. We fit a single temperature APEC spectrum to each source and search for significant periodicities in the fitted APEC flux using a Lomb-Scargle Periodogram (LSP). Since errors are not taken into account in the LSP, we use Monte Carlo simulations to consider the APEC flux errors. No clear X-ray cycle is detected for any of the stellar sources in our sample. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 0754568 and by the Smithsonian Institution.

348.08 – **RR Lyrae Variables In The Ultraviolet: The View From GALEX**

Jonathan Wheatley[1], B. Y. Welsh[1], S. E. Browne[2]

[1]University of California Berkeley, [2]Eureka Scientific, Inc.

9:00 AM - 6:30 PM

The GALEX ultraviolet survey has serendipitously obtained complete FUV (1350-1800A) and NUV (1800-2800A) light curves of several RR Lyrae stars, such as HL Her and SDSS J105622.2+570520.6 . Using visible photometry (obtained at the Lick Observatory) together with the GALEX UV data we compare these light curves with predictions based on Kurucz stellar atmosphere models. A FUV variation of 6.5 stellar magnitudes in SW Aqr is consistent with theoretical predictions based on the published metallicity of this star.

348.09 – **Variable Uv-source Catalog From The Galex Database**

Nitish Chopra[1], A. Conti[2], L. Bianchi[3]

[1]University of Wisconsin, [2]STScI, [3]Johns Hopkins University.

9:00 AM - 6:30 PM

We present the first part of a comprehensive program to look for variability in the UV GALEX archive (Conti et al. 2011, ApSS, 335,:329); GALEX provided photometric measurements for over 200 million objects in FUV and NUV, from sky surveys with different depth and coverage (Bianchi 2009, ApSS, 320:11, Bianchi et al. 2011, MNRAS, 411:2770, Bianchi 2011 ApSS 335:51). In this work, out of 410,408 unique sources showing conspicuous variability in both NUV and FUV from a total of 2,106,816 measurements, we restrict our analysis to 7264 sources that have at least 30 measurements, sampled with serendipitous time coverage. This first sample selection includes both extragalactic sources and Milky Way stellar objects, displaying both periodic and non-periodic variability, of various types including RR Lyrae, flare stars, transients, and eclipsing binaries. Amplitudes of magnitude variations are found from our minimum selection threshold up to > 0.6 AB mag. We describe the selection criteria and procedures, we characterize the main classes of variables within the sample, and present the layout of the resulting catalog which will be also available as on-line resource.

Beyond our immediate goals of discovering and characterizing UV-selected variables, this work

provides synergy with existing and planned surveys at other wavelengths (e.g. SDSS, PanSTARRS, LSST, GAIA) and the methods will be applicable to larger databases.

Acknowledgements: This work was part of NC 2011 summer internship at STScI; LB was partly supported by the GALEX project.

348.10 – **On The Variability Of MWC 349A: Continuum Versus Hα Emission**

Alexander Hillbrand[1], V. Strelnitski[2], D. Sliski[2], G. Walker[2], B. Bosworth[3]

[1]Cornell U. & Maria Mitchell Obs., [2]Maria Mitchell Obs., [3]Mass. Coll. of Art & Design & Maria Mitchell Obs..

9:00 AM - 6:30 PM

We report on a photometric monitoring of MWC 349A with the CCD-equipped Maria Mitchell Observatory's 24-inch telescope in 2009-2011. The goal of the project was to separate the Hα emission line variations from those of the continuum. We present our new method of the line/continuum separation (based on observations with two interference filters of different widths centered on Hα) and the results of the monitoring. Variations of both the red continuum and the Hα emission with amplitudes up to 0.1 magnitude on relatively short time scales (weeks and months) were superimposed on a secular drop of the star's brightness by approximately 0.3 magnitudes during the past 15 years. More recently, we found that the previously suspected periodicity with the period

of ca. 240 days was followed by a long (more than a year) interval of virtually constant brightness. In our method of line/continuum separation, random and systematic errors in the outcomes from the two filters create an artificial anti-correlation between the extracted line and continuum intensities. However, considerable anti-correlation was observed even after smoothing the data for periods as long as a month. On shorter time scales, possible intrinsic anti-correlation has been corroborated by separating the emission line from the continuum with two independent filter combinations. If the intrinsic anti-correlation is real, it can be explained by the well-known inverse dependence of the recombination line emissivity on electron temperature, the latter being directly proportional to the ionizing ultraviolet continuum of the star. This project was supported by NSF/REU grant AST-0851892, the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring and the Nantucket Maria Mitchell Association.

348.11 – **Observations of Suspected RR Lyrae Variable Stars**

Caleb Bahr[1], H. Amende[1], W. Powell Jr.[1], R. Wilhelm[2]

[1]*Texas Lutheran University,* [2]*University of Kentucky.*

9:00 AM - 6:30 PM

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.

348.12 – **A Mid-infrared Study of RR Lyrae Stars with the WISE Preliminary Data Release**

Tatyana Gavrilchenko[1], C. R. Klein[1], J. S. Bloom[1], N. R. Butler[2]

[1]*University of California, Berkeley,* [2]*Arizona State University.*

9:00 AM - 6:30 PM

Understanding RR Lyrae pulsating variable stars in mid-infrared wavebands can lead to more accurate distance measurements and consequently improve the cosmic distance ladder. We present a group of >1000 previously identified RR Lyrae variables well-observed with the Wide-field Infrared Survey Explorer (WISE) telescope, combining published optical periods and mid-IR-derived periods. We explore how the shape of the generic RR Lyrae mid-infrared light curve evolves in period-space, comparing the structural features of the light curves in mid-infrared bands to those present in optical bands. From the period-space analysis, we hope to improve the classification methods of RR Lyrae variables, which affect their potential as distance indicators by minimizing distance uncertainty.

348.13 – **First Detection of Far-IR Variability in M33 and M101**

Edward J. Montiel[1], C. W. Engelbracht[1], G. C. Clayton[2]

[1]*Steward Observatory,* [2]*Dept. of Physics & Astronomy, Louisiana State University.*

9:00 AM - 6:30 PM

We present our analysis of multiple epochs of archival MIPS 24 micron imaging of the spiral galaxies M33 and M101. We detect the first signature of variability in 287 and 178 point sources in M33 and M101, respectively. At these wavelengths we believe that we are most likely seeing Young Stellar Objects (YSOs) and/or Asymptotic Giant Branch stars (AGBs). Recent evidence has suggested that infrared variability reveals insights into the dynamics between YSOs and AGBs and their surrounding dust shell. We explore the nature of these objects with a suite of ancillary data from the far-UV to sub-mm wavelengths and what we learn about star formation and evolution in environments different from the Milky Way galaxy.

348.14 – **Near-infrared Period-Luminosity relations of Large Magellanic Cloud Cepheids**

Michael T. Smitka[1], L. M. Macri[1], S. Kanbur[2], F. Ripple[2], C. Ngeow[3]

[1]*Texas A&M University,* [2]*SUNY-Oswego,* [3]*National Central University, Taiwan.*

9:00 AM - 6:30 PM

We present near-infrared time-series PSF photometry of over 1,600 LMC Cepheids previously discovered by the OGLE III survey. The goal of this work is to improve the near-infrared Cepheid P-L relation in the LMC, often used as an anchor of the Extragalactic Distance Scale. We also wish to determine the presence of non-linearities in the slopes of these relations.

Observations were obtained using CPAPIR at the CTIO 1.5m telescope as part of the NOAO/SMARTS program. We present details of our analysis, including photometric calibration using 2MASS, preliminary light curves, and Period-Luminosity relations.

348.15 – **A search for Cepheids in NGC 5584 using Difference Image Analysis**

Samantha L. Hoffmann[1], L. M. Macri[1], A. G. Riess[2], SHOES team

[1]*Texas A&M University,* [2]*Johns Hopkins University/Space Telescope Science Institute.*

9:00 AM - 6:30 PM

A more precise and accurate measurement of the Hubble constant (H0) via Cepheids and type Ia supernovae imposes significant additional constraints on the equation of state of dark energy. We recently carried out a search for Cepheids in NGC 5584, host of the type Ia supernova 2007af, as part of an ongoing program to determine H0 with a total uncertainty below 3%.

We surveyed NGC 5584 with HST/WFC3 over 13 epochs spanning 100 days. We searched for Cepheids using point-spread function (PSF) and difference image analysis (DIA) techniques. We present the samples of Cepheid candidates found with each method and compare their performance for finding Cepheids in crowded fields.

We acknowledge support by NASA through grant HST-GO-11570.

348.16 – **Low-Frequency Temporal Variability in Mira and Semiregular Variables**

Matthew R. Templeton[1], M. Karovska[2], E. O. Waagen[1]

[1]*AAVSO,* [2]*Harvard-Smithsonian Center for Astrophysics.*

9:00 AM - 6:30 PM

We investigate low-frequency variability in a large sample of Mira and semiregular variables with long-term visual light curves from the AAVSO International Database. Our aim is to determine whether we can detect and measure long-timescale variable phenomena in these stars, for example photometric variations that might be associated with supergranular convection. We analyzed the long-term light curves of 522 variable stars of the Mira and SRa, b, c, and d classes. We calculated their low-frequency time-series spectra to characterize rednoise with the power density spectrum index, and then correlate this index with other observable characteristics such as spectral type and primary pulsation period. In our initial analysis of the sample, we see that the semiregular variables have a much broader range of spectral index than the Mira types, with the SRb subtype having the broadest range. Among Mira variables we see that the M- and S-type Miras have similarly wide ranges of index, while the C-types have the narrowest with generally shallower slopes. There is also a trend of steeper slope with larger amplitude, but at a given amplitude, a wide range of slopes are seen. The ultimate goal of the project is to identify stars with strong intrinsic red noise components as possible targets for resolved surface imaging with interferometry.

348.17 – **Analysis Of Low-amplitude Variations In The Light Curves Of FF Aqr And HD 185587**

Keenan M. Stone[1], T. R. Vaccaro[1]

[1]*Francis Marion University.*

9:00 AM - 6:30 PM

There are unexplained small amplitude variations seen in the B light curves of the eclipsing binary FF Aqr that appear to emanate from the chromospherically active giant. Fourier analysis with the Period04 program performed on data obtained during several eclipses of the hot compact companion showed multiple frequencies with little consistency in their values between each eclipse. Additional variations are also apparent outside of the eclipse.

While investigating the analogous system V1279 Aql for similar variations, it was found that the check star in this field (HD185587) exhibited regular variations and may be a low amplitude Delta Scuti type of variable.

348.18 – **MOST Observations of the Trapezium Region**

Arne A. Henden[1], M. R. Templeton[1], W. Herbst[2], J. A. Guzik[3]

[1]*AAVSO,* [2]*Wesleyan University,* [3]*Los Alamos National Laboratory.*

9:00 AM - 6:30 PM

During December 2010 and January 2011, the MOST satellite monitored the Trapezium region of Orion, centered on the 6.5-day eclipsing binary BM Orionis. Month-long light curves of this eclipsing binary along with 37 other stars were obtained by the spacecraft, along with extended monitoring from AAVSO observers. A detailed analysis is ongoing. First, we briefly describe our methodology for removing scattered light and other systematic effects from the data. Our results for the BM Ori light curve show that the light curve is symmetric and flat-bottomed, and our analysis shows that duration of total eclipse is now shorter than was previously measured. No other periodic signals have thus far been detected in BM Ori. MOST data for several other stars in the Orion region clearly show either aperiodic variability, or periodic variations suggesting rotation, and we survey the result of our variability search. Among the MOST light curves is a nearly unbroken 27-day light curve of the bright Be star MWC 114, and multiperiodic variability is clearly visible.

348.19 – **The LINEAR Photometric Database: Time Domain Information for SDSS Objects**

Mark Veyette[1], A. C. Becker[1], H. Bozic[2], P. Carroll[1], P. Champey[3], Z. Draper[1], N. Evans[1], A. Filbrandt[1], J. Fowler[1], J. Gailey[1], M. Galin[2], Z. Ivezic[1], Z. Jennings[1], J.

Kelley[1], A. Kroflin[2], C. Laws[1], E. Lewarch[1], S. Loebman[1], L. Mayorga[1], M. Mesaric[2], D. P. Morgan[4], P. Munk[2], H. Oluseyi[3], L. Palaversa[5], M. Patel[3], D. Ruzdjak[2], S. Schmidt[1], B. Sesar[6], G. Srdoc[2], K. Steakley[1], J. S. Stuart[7], D. Sudar[2], D. Vrbanec[2], D. B. Westman[1], S. Wheaton[1], P. Wozniak[8]

[1]University of Washington, [2]University of Zagreb, Croatia, [3]Florida Institute of Technology, [4]Boston University, [5]Geneva University, Switzerland, [6]California Institute of Technology, [7]Massachusetts Institute of Technology, [8]Los Alamos National Laboratory.
9:00 AM - 6:30 PM

We announce a public database of over 5 billion photometric measurements for about 25 million objects, mostly stars with V<18, obtained by the asteroid survey LINEAR (available through the SkyDot website, skydot.lanl.gov). With 200 observations per object on average, LINEAR data provide time domain information for the brightest 4 magnitudes of SDSS survey objects. By combining information from these databases we have selected and visually classified some 200,000 candidate variable stars. Guided by these classifications, we selected the largest available sample of candidate field SX Phe stars (blue straggler halo stars) and demonstrated its low contamination through follow up observations at a number of telescopes in Croatia and the U.S. We have also constructed samples of several thousand distant RR Lyrae stars, as well as several thousand eclipsing binary stars, and are currently investigating the statistical properties of these data.

348.20 – **Waves In Accretion Disks, Observed With Fresno State'S Station At Sierra Remote Observatories: Hv Andromedae, Lq Pegasi, And Ln Ursae Majoris**

Gerald Rude[1], F. A. Ringwald[1]

[1]California State University Fresno.
9:00 AM - 6:30 PM

We present observations of three cataclysmic variable stars: HV Andromedae, LQ Pegasi, and LN Ursae Majoris. A cataclysmic variable star is a binary star system composed of a red dwarf orbiting a white dwarf. These stars orbit closely, typically in

3-4 hours. Due to this close orbit, gas spills from the red dwarf into orbit around the white dwarf. This forms an accretion disk. Accretion disks are found throughout the Universe: from planetary formation, Saturn's rings, black holes that swallow stars, to the Milky Way's spiral structure. Our goal in studying these three cataclysmic variables was to search for evidence of waves, warping, or bending of their accretion disks.

Photometry is the study of how the brightness of an object changes over time. With cataclysmic variables much of the fluctuation in brightness is from the accretion disk. We collected time-resolved differential photometry of three cataclysmic variables using Fresno State's remotely controlled telescope at Sierra Remote Observatories. After measuring our photometry, we searched for waves in the data.

We have surprising results for each of the stars studied. All of these objects have prominent low-frequency periodicities not seen in the literature. This can be attributed to Fresno State's Remote Observatory's ability to observe stars for extended periods of time. We found strong evidence for both warping and bending waves in LQ Pegasi. In LN Ursae Majoris, we discovered apparently chaotic behavior, with the low-frequency wave changing significantly in just under a month. We also see clear evidence for short-period waves in HV Andromedae, also with some rumbling at low frequencies. Our observations of these three cataclysmic variables, especially of LN Ursae Majoris, warrant further study in the form of radial-velocity studies.

348.21 – **The 100,000-Magnitude Light Curve For the Eruption of Recurrent Nova T Pyx**

Bradley E. Schaefer[1]

[1]Louisiana State Univ..
9:00 AM - 6:30 PM

The recurrent nova T Pyx erupted on 14 April 2011, its sixth known eruption. As part of an intensive campaign organized by the AAVSO, T Pyx now has ~100,000 points in its eruption light curve. The coverage for T Pyx exceeds by far the second place (36,776 magnitudes for U Sco in 2010) and the third place (~3000 magnitudes for RS Oph in 2006) nova light curves. (1) T Pyx underwent a mysterious pre-eruption rise 11 days before the start of the fast rising thermonuclear explosion, brightening to 1.1 mag above the quiescent level, then returning towards quiescence before the start of the eruption. (2) T Pyx is the first-ever nova that has been followed from the start of the fast rise, and in this case with fast times series and multicolor photometry. For the first 2.0 days, the light curve is well fit by a uniformly expanding shell model, only to then suffer a slight decline in brightness. (3) The pre-eruption orbital period was measured just 40 days prior to the eruption to be 0.07622916+-0.00000008 days. (4) The eruption light curve up to 120 days after the start of the eruption was virtually identical with the light curves from all prior eruptions. But starting at day 125, the light curve has continued declining slowly, rather than the sudden sharp drop by two magnitudes as was seen in the 1967 light curve. (5) The surprisingly short interval between the 1967 and 2011 eruptions is now no longer surprising with the realization that the accretion rate is proportional to the blue flux, so the drop in the average accretion rate from 1944-1967 (22 years) to 1967-2011 (44.33 year) by a factor of two implies an eruption date of 1967+2X22 = 2011.

Supported by the National Science Foundation (AST-1109420).

348.22 – **Expansion of the Nova Shell Around Z Cam**

Trisha Mizusawa[1], M. Shara[1], D. Zurek[1]

[1]American Museum of Natural History.
9:00 AM - 6:30 PM

Z Camelopardis (Z Cam) is a bright dwarf nova with an asymmetrically expanding old nova shell. We obtained Kitt Peak 4m images narrowband [NII] from two epochs, three years apart, to measure or constrain expansion of the shell. Several experiments to map the edge of the circular arc part of the shell demonstrate that it has expanded less than a single pixel in three years. This supports an age significantly in excess of 1,000 years for the shell of Z Cam.

348.23 – **Toward a Unified Understanding of Radio Emission from Novae**

Traci Johnson[1], M. Krauss[2], M. Rupen[2], A. Mioduszewski[2], L. Chomiuk[2], J. Sokoloski[3], N. Roy[2]

[1]Carleton College, [2]National Radio Astronomy Observatory, [3]Columbia University.
9:00 AM - 6:30 PM

The radio continuum emission from novae is thought to arise predominately from thermal bremsstrahlung, which is relatively easy to model and interpret physically. However, highly sensitive and more frequent and earlier sampling methods used in the observations of recent galactic novae using the Expanded Very Large Array (EVLA) show startlingly different results from previous observations, and cannot be modeled using the previous simplistic models. To explore the apparent discrepancy between the new EVLA data and previous observations, we present a complete collection of all historical radio observations of novae. This allows us to make comparisons which help determine if the observed deviations are due to fundamental physical differences, or are simply a function of the more frequent and better-sampled newer data. Thirteen multi-frequency data sets are included in the collection: nine from a literature search and four from the VLA archive. The nine published novae were fitted to the simple model of expanding spherically-symmetric thermal shells -- three of which had no prior model fit performed. We conclude that some of the deviations from the simple model seen in the new data may be present in the older data sets; however, there is both too few data and large errors on much of that data for any of these results to be conclusive. We discuss possible model modifications that could be made and provide suggestions for future observations of novae which could provide better clues into the true nature of nova outbursts.

348.24 – **Water Masers of Water Fountain Pre-Planetary Nebula IRAS 16342-3814**

Hannah Rogers[1], M. Claussen[2], M. R. Morris[3], R. Sahai[4]

[1]Augustana College / NRAO REU, [2]National Radio Astronomy Observatory, [3]UCLA, [4]Caltech / JPL.
9:00 AM - 6:30 PM

The water fountain pre-planetary nebula IRAS 16342-3814 was observed approximately monthly over a period of a year with the Very Large Array (VLA) and the Very Long Baseline Array (VLBA) of the National Radio Astronomy Observatory. The new observations, from 2008, were compared to observations from the VLA and VLBA in 2002 and observations using the NRAO 140-foot telescope in 1992. The spectra of the water masers within the pre-planetary nebula show a new and very strong maser around -3 km/s, and previously observed slightly blue shifted water masers are no longer visible. The velocity spread covered by the water masers has increased from 260.4 km/s to 307.9 km/s between 1992 and 2008. There was a slight decrease in the velocity spread of 2002 to 244.7 km/s. Unlike past observations of this pre-planetary nebula, the water masers do not show symmetry about a central systemic velocity. The length of the line (projected on the sky) joining the extreme blue- and red- shifted water masers also appears to have stopped growing at a length of 3104.0±0.2 mas, even though the increased range in the line of sight velocities suggests that the water masers are moving outwards faster than before. Ideas which may turn into models are currently being developed to explain this phenomenon.

The NRAO is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc. Part of this research was carried out under the auspices of the National Science Foundation's Research Experience for Undergraduates (REU) program at the NRAO, and we gratefully acknowledge the funding for this program.

349 – Molecular Clouds, HII Regions, Interstellar Medium

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

349.01 – **The G1 Intermediate-velocity Cloud:low-metallicity Gas Streaming Away From The Galaxy**

Barry Welsh[1], R. Lallement[2], J. Wheatley[1]

[1]*UC, Berkeley,* [2]*GEPI, Observatoire de Paris, CNRS, Meudon, France.*

9:00 AM - 6:30 PM

We present medium resolution (R ~ 15 km/s) ultraviolet absorption measurements recorded with the HST-Cosmic Origins Spectrograph towards two post-AGB stars located within the M15 globular cluster. By sampling interstellar gas over the 10.4kpc sight-line we have revealed spectral absorption features associated with the foreground g1 Intermediate Vleocity Cloud (IVC), whose distance lies between 1.8 - 3.8 kpc.

The UV line-profiles reveal IVC absorption at a velocity of V(lsr) ~ +61.5 km/s, in both low and high ionization ions. The derived column density ratios of [OI/H] = -1.22+/-0.44 and [NI/H] = -1.21+/-0.38 suggest an appreciable sub-solar metallicity for the out-streaming gas. The more highly ionized gas possesses higher than solar abundance ratios relative to that of O. A possible origin for this IVC is that of a low metallicity cloud that has been accreted towards our galaxy, has passed through the disk and is now moving away from the galactic plane.

349.02 – **Effects of Shear and Magnetic Fields on Molecular Cloud Formation in the Flow-Driven Picture in 2D**

Christina M. Haig[1], F. Heitsch[1], J. Carroll[2], A. Frank[2]

[1]*University of North Carolina, Chapel Hill,* [2]*University of Rochester.*

9:00 AM - 6:30 PM

We present a parameter study addressing the ramifications of shear in the flow-driven scenario of molecular cloud formation. Previous studies in two and three dimensions of this cloud and core formation picture have not included the exploration of a more realistic scenario of flows colliding at an angle. The introduction of shear is accomplished by varying the angle of the initial interface between two supersonic colliding flows, which introduces additional overall angular momentum to the molecular cloud. Shear in these flows can also inhibit global and local collapse, but still permits the formation of dense cores at regularly spaced intervals in the final cloud. In this work we are primarily concerned with the effects on the energy balance and angular momentum distribution of the resulting protostellar cores, and how these outcomes change as magnetic fields are included. A secondary concern is how the overall core formation rate is affected by the changes in angle and initial Mach number of the flow. These simulations are done in AstroBEAR, an MHD code capable of adaptive mesh refinement with self-gravity.

349.03 – **<Cosmic Origins Spectrograph Observations of the Heavily-Reddened Star NCG 2024 Number 1.**

Theodore P. Snow[1], E. Burgh[1], J. Destree[1], D. Anderson[1], R. Ferguson[1]

[1]*Univ. of Colorado.*

9:00 AM - 6:30 PM

The Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope has been observing translucent interstellar clouds to derive elemental depletions, molecular abundances, physical conditions as well as a search for UV diffuse interstellar bands. Of the six stars in our GTO program, by far NGC 2024 No. 1 is the faintest and most reddened, at V = 12.17, B = 13.58, E(B-V) = 1.41, Rv ≈ 5.5, and Av ≈7.8. Thus this star, in the Flame nebula in Orion, has probably the most interstellar gas and dust we will ever observe in UV spectra, pending future space telescopes. By far H2 (estimated from its correlation CH) is the dominant form of hydrogen and almost all of the carbon is in CO molecules, which is unprecedented in UV spectra. We report the hydrogen and CO column densities, depletions of a few elements, molecular abundances, the UV extinction curve, and diffuse bands in the visible spectrum.

349.04 – **Snakes in the Plane: Direct Imaging of Magnetized Turbulence in the Interstellar Medium**

Bryan M. Gaensler[1], M. Haverkorn[2], B. Burkhart[3], K. J. Newton-McGee[1], R. D. Ekers[4], A. Lazarian[3], N. M. McClure-Griffiths[4], T. Robishaw[5], J. M. Dickey[6], A. J. Green[1]

[1]*The University of Sydney, Australia,* [2]*Radboud University Nijmegen, Netherlands,* [3]*University of Wisconsin, Madison,* [4]*CSIRO, Australia,* [5]*DRAO, Canada,* [6]*University of Tasmania, Australia.*

9:00 AM - 6:30 PM

The interstellar medium (ISM) of the Milky Way consists of gas and dust at a range of temperatures and pressures, and provides the raw material from which stars and planets form. Astronomers have developed a sophisticated understanding of the ISM as a multi-phase, magnetized, turbulent medium. However, observations have lacked the sensitivity and resolution to directly image the small-scale structure associated with turbulent motions in the diffuse ISM. Radio polarimetry is a promising avenue for further progress, because Faraday rotation of linearly polarized radio signals provides a very sensitive probe of fluctuations in magnetic field and ionized gas density. Here we present a new way of processing images of linearly polarized radio emission from the ISM, in which we derive the gradient of the Stokes vector (Q,U). This provides the first direct image of supersonic turbulence in the ISM, manifested as a complex filamentary web of sharp density jumps. Application of the polarization gradient to both simulations and observations can allow the measurement of currently unconstrained parameters of interstellar turbulence such as the Mach number, Reynolds number and magnetic field strength.

349.05 – **An Ultraviolet and X-Ray Study of ISM Dust and Gas Toward Two LMXBs**

Adam G. Jensen[1], G. Sonneborn[2], N. Schulz[3], L. Valencic[2]

[1]*Wesleyan University,* [2]*NASA's GSFC,* [3]*MIT.*

9:00 AM - 6:30 PM

Analysis of chemical abundances and dust composition in the interstellar medium (ISM) suffers from spectroscopic information that is either incomplete or ambiguous. An improved analysis of ISM abundances and dust composition would involve spectroscopic information from multiple wavebands. We have obtained 13 orbits of Hubble Space Telescope/Cosmic Origins Spectrograph ultraviolet (UV) spectra of two low-mass X-ray binaries (LMXBs). We have also obtained optical spectra from the Hobby-Eberly Telescope (HET) and Harlan J. Smith Telescope (HJST) in order to assess the velocity structure of these lines of sight. These spectra allow us to analyze the gas-phase ISM column densities of H, O, and Fe toward these LMXBs. We then discuss the column density results in terms of existing Chandra X-Ray Observatory (CXO) results for these targets. The CXO data allow for the measurement of total gas+dust column densities of O, Ne, and Fe, allowing the combined data set to measure the total, phase-independent abundances of O, Ne, and Fe relative to H, and also separate the gas- and dust-phase components of O and Fe. This is a unique, direct measurement of the dust-phase composition of the ISM, which we discuss in the context of our current understanding of ISM abundances and dust models.

349.06 – **Faraday Rotation Measurements of the Super Bubble Associated with the Rosette Nebula**

Allison H. Savage[1], S. R. Spangler[1], P. D. Fischer[1]

[1]*University of Iowa.*

9:00 AM - 6:30 PM

The Rosette Nebula is an excellent candidate for studies of super bubbles associated with stellar associations. We made linear polarization measurements of background radio sources with the Expanded Very Large Array (EVLA) to explore the properties of the prominent stellar bubble associated with the Rosette Nebula. We report the results of Faraday rotation measurements of 23 extra-galactic radio sources whose lines of sight pass through or close to the Rosette Nebula. The observations were made at 4.4GHz, 4.9GHz, and 7.6GHz. We are able to establish a background rotation measure due to the galactic plane in the vicinity of the Rosette Nebula of ~140 rad/m2. Sources whose lines of sight pass through the nebula have an excess rotation measure of 300 -700 rad/m2, which we attribute to the plasma shell of the Rosette Nebula. We discuss two simple plasma shell models that can account for the magnitude of the rotation measure, and its dependence on distance from the center of the nebula. These two models represent different modes of interaction of the Rosette Nebula star cluster with the surrounding interstellar medium. This research was supported at the University of Iowa by grant AST09-56901 from the National Science Foundation.

349.07 – **Cosmic Origins Spectrograph Observations of Translucent Clouds**

Eric B. Burgh[1], T. P. Snow[1], J. D. Destree[1], R. M. Ferguson[1], A. A. Youngblood[1], D. K. Anderson[1], K. France[1]

[1]*Univ. of Colorado, Boulder.*

9:00 AM - 6:30 PM

The high sensitivity of the Hubble Space Telescope's Cosmic Origins Spectrograph allows for the observation of heavily reddened OB stars unobservable by preceding ultraviolet spectrographs. We present measurements of the metal and molecular content along six sightlines sampling the translucent interstellar medium, with A_V ranging from 2.7 to 7.6. We find that the sample includes both sightlines that are concatenations of multiple diffuse clouds as well as sightlines sampling true translucent material. In these latter regions we find that molecular fractions, metal depletions, CO to H_2 ratios and CO rotational excitation temperatures are all enhanced. We discuss the physical and chemical properties of these sightlines in the context of previous observations of the diffuse and translucent interstellar medium.

349.08 – **Mapping the Magnetic Field of Cloud 3 in Lynds 204**

Lauren Cashman[1], D. P. Clemens[1]

[1]*Boston University.*
9:00 AM - 6:30 PM

The L204 dark cloud complex is a nearby filamentary structure in Ophiuchus that is devoid of star formation. Past studies have shown that the western edge of L204 exhibits a steep density gradient, while the eastern edge gradually dissipates. We have collected H-band (1.6 microns) linear polarimetry data for starlight in the direction of L204, as well as NIR spectra of several stars in the field. The data were collected using the Mimir near-infrared instrument on the 1.8m Perkins Telescope located outside of Flagstaff, AZ. These data are presented alongside integrated intensity maps of 12CO, 13CO, and C18O in order to reveal how the magnetic field in L204 is affecting the physical structure and evolution of the cloud.

This work is partially supported by NSF grant AST 09-07790.

349.09 – **Self-sustained Magnetized Clumps And Their Interaction With Shocks**

Shule Li[1], A. Frank[1]

[1]*University of Rochester.*
9:00 AM - 6:30 PM

Problems involving magnetized clouds and clumps, especially their interaction with shocks are crucial in astrophysical context and have been thoroughly studied in the past decade. Many previous numerical studies focus on the problem of clumps placed in a global uniform magnetic field run through by a shock. However, the realistic clumps usually have tangled magnetic field centralized inside them. The difficulty in such a study is that it is hard for the numerically created clumps to sustain themselves under such circumstance, especially with low magnetic beta. AstroBEAR is a parallel MHD code with adaptive mesh refinement. With the new AstroBEAR code, it is possible to create self-sustained clumps with tangled magnetic field residing inside them. Moreover, the recently built in multi-physics functionality allows us to incorporate realistic micro-physics resistivity and viscosity in the simulation thus allowing for more realistic treatment to the magnetized clump problem. In this study, we examine the long term evolution of self-sustained magnetized clumps with centralized tangled magnetic field and their interaction with shocks.

349.10 – **Mapping Dust Across Kiloparsec-Scale Areas of M31 with the Panchromatic Hubble Andromeda Treasury (PHAT)**

Julianne Dalcanton[1], A. K. Leroy[2], K. D. Gordon[3], D. Lang[4], B. F. Williams[1], PHAT Collaboration

[1]*Univ. of Washington,* [2]*NRAO,* [3]*STScI,* [4]*Princeton University.*
9:00 AM - 6:30 PM

The Panchromatic Hubble Andromeda Treasury (PHAT) is a Hubble Space Telescope Multi-Cycle Treasury program to image ~1/3 of M31 at HST resolution from the UV through the NIR. We use PHAT's NIR observations of red giant branch stars to characterize the dust distribution over many square kiloparsecs of the star forming disk, with a resolution of better than 50 parsecs. We demonstrate the effectiveness of our new mapping technique, and then compare the resulting dust maps to other probes of the interstellar medium. We find good agreement overall between these new high resolution extinction maps and other tracers of the cold ISM. However, we also see interesting departures that should yield insight into variations of the X_CO factor, particularly when combined with constraints available from the UV and optical stellar populations revealed by PHAT.

349.11 – **The Ultra-compact HII Region G31.41+0.31 Revisited: A Radio Continuum and Infrared Study**

Charity J. Southworth[1]

[1]*Indiana University.*
9:00 AM - 6:30 PM

Radio continuum images of ultra-compact HII regions have played an important role in investigating the rate of massive star formation in the Milky Way Galaxy. To fully comprehend the physics of ultra-compact HII regions multi wavelength, and multi-resolution studies are necessary. Here we present radio continuum images obtained with the VLA toward the prominent ultra-compact HII region G31.41+0.31. The observations were made in the A-configuration at 20 cm, 6 cm, 3.5 cm, 1.3 cm and the A, and B configurations at 0.7 cm. We use this data to investigate the morphology of the region, the ionization requirements and the probable history of massive star formation. We find that the ultra-compact HII region is part of a much larger structure visible at 20 cm, and likely contains several generations of massive star formation. We also include NIR and Mid-IR images, to obtain information about the stellar component in the region.

The NRAO is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc. Part of this research was carried out under the auspices of the National Science Foundation's Research Experience for Undergraduates (REU) program at the NRAO, and we gratefully acknowledge the funding for this program.

349.12 – **The Emission Nebula Sh2-231 And Its Relation To The Dust Cloud TGU 1192 (LDN 1525)**

Richard P. Boyle[1], R. Janusz[1], V. Straizys[2], V. Laugalys[2]

[1]*Vatican Observatory,* [2]*Vilnius University, Lithuania.*
9:00 AM - 6:30 PM

The HII region Sh2-231 is thought to belong to the Auriga OB1 association, together with other emission nebulae, Sh2-232, Sh2-233 and Sh2-235, all within 1 square degree. The area is surrounded by a giant molecular cloud G173.7+02.7 also known as a dust cloud LDN 1525 or TGU 1192. Distances estimated from the exciting stars of the HII regions are known with low accuracy (between 1.0 and 2.3 kpc). Most authors consider that all listed HII regions are related to the association Aur OB1: the mean distance of its stars is 1.3 kpc. In our earlier paper (Straizys et al., Baltic Astronomy, 19, 169, 2010) we argued the Sh2-231 nebula might not be related to the association. More probably this nebula is in the Perseus arm seen semi-transparently through the dust cloud TGU 1192.

We investigate the 12' by 12' area using the VATT telescope with a 4K CCD camera and seven filters of the Vilnius photometric system to determine spectral and luminosity classes, interstellar reddenings, extinctions and distances for the field stars down to V = 17 mag. Thus we learn the distance to the dust cloud and its relation to the nebula Sh2-231. IPHAS and MegaCam photometry provides spectral types for fainter stars.

Both Vilnius and IPHAS photometric data are in agreement that the dust cloud in the direction of Sh2-231 begins at a distance of about 1.3 kpc, i.e., it is undoubtedly related to the Aur OB1 association. The extinction Av in the cloud ranges between 1.5 and 4.5 mag. However, the star ALS 8476 (O9 V, V = 10.79, Av = 3.6, d = 2.3 kpc) is too far to be related to the Aur OB1 star-forming region. Consequently, if this star is the exciting source of Sh2-231, the nebula belongs to the Perseus arm.

349.13 – **Locating New Sites of Massive Star Formation With WISE**

Loren D. Anderson[1], T. M. Bania[2], D. S. Balser[3]

[1]*West Virginia University,* [2]*Boston University,* [3]*NRAO.*
9:00 AM - 6:30 PM

The Wide-Field Infrared Survey Explorer (WISE) has the power to detect star formation regions over the entire Galactic disk at extreme distances from the Sun. WISE covers the entire sky at wavelengths from 3μm to 25μm, although the data released thus far cover approximately l=60° to -60° and l=120° to 240° along the Galactic plane. The Galaxy flares in the outer part of the disk, and therefore the most distant star forming regions are found off the plane at high and low Galactic latitudes. These parts of the Galaxy were largely not observed by the Spitzer Legacy projects. We have shown in previous work the utility of mid-infrared data in locating previously unknown HII regions, and we have developed infrared color criteria to locate HII regions. Here we report on an ongoing survey to locate star formation sites with WISE and we analyze the properties of the detected candidate star forming regions.

349.14 – **The Polarized ISM Toward and Beyond Open Cluster NGC 6802**

April Pinnick[1], D. P. Clemens[1]

[1]*Boston University.*
9:00 AM - 6:30 PM

Dust grains aligned to their local Galactic magnetic field impress polarization upon background starlight. Identifying and characterizing the polarized interstellar medium constrains the topology of the Galactic magnetic field and the distribution of dust in the Galaxy. We present near-infrared H-band (1.6 microns) imaging polarimetry of the cluster and field stars toward NGC 6802, taken with Mimir on the Perkins telescope outside Flagstaff, AZ. We identify and characterize three distinct polarizing regions. Implications for the large-scale structure of the Galactic magnetic field are also discussed.

This work partially supported by NSF grant AST 09-07790.

349.15 – **A Detailed Chandra Study of the Interstellar Medium Metallicity in the Large Magellanic Cloud**

Andrew Schenck[1], C. Boone[1], D. Burrows[2], J. Hughes[3], J. Lee[4], R. Lord[1], K. Mori[5], S. Park[1], S. Post[1], P. Slane[6]

[1]*University of Texas at Arlington,* [2]*Penn State Univ.,* [3]*Rutgers Univ.NJ,* [4]*Korea Astronomy and Space Science Institute, Korea, Republic of,* [5]*Univ of Miyazaki, Japan,* [6]*Harvard-Smithsonian, CfA.*
9:00 AM - 6:30 PM

Measurements of interstellar composition are essential for understanding galactic evolution and the star-formation history of the Milky Way and other nearby galaxies. The Large Magellanic Cloud (LMC) is an excellent candidate for the study of the Interstellar Medium (ISM) thanks to its proximity and low foreground absorption. X-ray spectroscopy of supernova remnants (SNRs) is independent of and complementary to the traditional optical spectroscopy of stars and HII regions for measuring metal abundances of gas-phase ISM. The LMC abundances currently available in the literature are based on data more than a decade-old. In particular, X-ray measurements were derived from a small number of SNRs observed by low resolution (~3') ASCA detectors which were not able to avoid contamination from embedded metal-rich ejecta

and/or pulsar wind nebulae. With high-resolution (0.5") Chandra data we can clearly isolate the swept-up ISM shells from central metal-rich ejecta and/or pulsar wind nebulae to estimate the 'true' metal abundances of the LMC ISM. Now, several dozens of LMC SNRs have been observed by Chandra, providing a large sample and diversity needed for accurate measurements of ISM abundances across the entire galaxy. We present our initial results on the O, Ne, Mg, Si, and Fe abundances of 17 LMC SNRs. We found our values to be typically lower than previously measured.

349.16 – **The Interstellar Medium in the Kepler Search Volume**

Marshall C. Johnson[1], A. G. Jensen[2], S. Redfield[2]

[1]*University of Texas at Austin,* [2]*Wesleyan University.*
9:00 AM - 6:30 PM

We present the results of a study of interstellar medium (ISM) clouds within the *Kepler* search volume. The density of the ISM surrounding a star affects the size of its astrosphere, in turn impacting the cosmic ray flux within the astrosphere, potentially having consequences for the climate and habitability of any planets orbiting the star. The greatest concentration of known planets will soon be in the *Kepler* search volume, and so we investigate the ISM in this direction. We used the 2.7-m Harlan J. Smith Telescope at McDonald Observatory to obtain high-resolution spectra of a sample of early-type stars within the *Kepler* field of view, spread over a wide range of distances. We fit the interstellar Na I and K I lines to derive parameters for ISM clouds along the line of sight to these stars and construct a preliminary map of clouds within the *Kepler* search volume.

349.17 – **GALFA HI: Needles as a New Measure of Interstellar Magnetic Fields**

Joshua Goldston Peek[1], GALFA-HI Survey Team

[1]*Columbia University.*
9:00 AM - 6:30 PM

We find that high resolution observations of the diffuse HI ISM show ubiquitous needle features: thin, dim, straight enhancements stretching many degrees across the sky. These features have only been recently uncovered by GALFA-HI due to the unprecedented combination of sensitivity, resolution, and area the survey provides. We present a new method to extract these features in a systematic and statistically robust way using a modified version of the Hough transform. We show a startlingly strong correlation between the orientation of these filaments and the orientation of the polarization of background starlight, indicating that needle orientation and magnetic orientation are very highly correlated. Needles can therefore act as a probe of magnetic orientation throughout the ISM and may be a probe of shearing or stretching in our Galaxy.

349.18 – **The GALFA-HI Survey: Analyzing The New Ultra-Compact Cloud Catalog.**

Destry R. Saul[1], J. E. G. Peek[1], J. Grcevich[1], M. E. Putman[1], K. A. Douglas[2], E. J. Korpela[3], S. Stanimirovic[4], C. Heiles[3], M. Lee[4], S. J. Gibson[5], A. Begum[4], A. R. H. Brown[1], B. Burkhart[4], E. T. Hamden[1], N. M. Pingel[4], S. Tonnesen[6]

[1]*Columbia University,* [2]*Arecibo Observatory,* [3]*University of California, Berkeley,* [4]*University of Wisconsin, Madison,* [5]*Western Kentucky University,* [6]*Princeton University.*
9:00 AM - 6:30 PM

The GALFA-HI Ultra-Compact Cloud Catalog contains over 2000 neutral hydrogen clouds associated with the Galaxy that are smaller than 20'.

The properties observable at 21cm, such as position, velocity, size, and linewidth, have allowed us to separate the catalog into five populations. These include cold and warm low-velocity clouds, high-velocity clouds, galaxy candidates, and low-velocity halo clouds. We will discuss the properties of each population and current investigations at other wavelengths.

349.19 – **Interferometric Images of the 36 GHz Methanol Masers in Star Forming Regions**

Hannah Seyb[1], V. Fish[2], L. Sjouwerman[3], Y. Pihlström[4]

[1]*Guilford College,* [2]*MIT Haystack Observatory,* [3]*National Radio Astronomy Observatory,* [4]*University of New Mexico.*
9:00 AM - 6:30 PM

Class I methanol masers are usually located in shocked environments near star forming regions. The EVLA upgrade has for the first time permitted interferometric observations of the 36 GHz Class I methanol transition. We report on images of the bright 36 GHz masers in 12 star-forming regions. Some sources show strong correlations between the locations of the 36 and 44 GHz Class I masers, while other sources show no correlation at all, suggesting that the ensemble of sources is representative of a large variety of physical conditions. For example, in the source G10.6-0.4 the 36 GHz masers were found to be located along a ridge of enhanced methanol density interacting with an outflow. In Sgr B2M, the 36 GHz masers trace an organized structure offset to the west of the main complex of ultracompact HII regions and Class II methanol masers. It will be important to analyze these results in the context of the thermal molecular environment of the masers in order to verify various models which describe the dependency on temperature, density, and column density of the Class I methanol masers. This work is made possible thanks to support from the National Science Foundation Research Experience for Undergraduates program.

349.20 – **Analysis Of The California Molecular Cloud Through CS J(2-1), HCN J(1-0), And C18O J(2-1)molecular Tracers**

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[1]*Department of Physics and Astronomy, California State Polytechnic University of Pomona,* [2]*Steward Observatory, University of Arizona,* [3]*Harvard-Smithsonian Center for Astrophysics,* [4]*UNAM-Ensenada, Mexico.*
9:00 AM - 6:30 PM

The California Molecular Cloud (CMC) is a nearby (D~450 pc) complex cloud with a total mass similar to the Orion Molecular Cloud but with only one-tenth the star formation rate. Studies of the CMC therefore provide a unique opportunity to probe the conditions of dense molecular gas in a quiescent star forming environment. We provide CS J(2-1) and HCN J(1-0) spectra taken with the Arizona Radio Observatory 12m telescope at Kitt Peak, as well as C18O J(2-1) spectra from the Heinrich Hertz Submillimeter Telescope on Mt. Graham, AZ, for 37 high opacity cores chosen from a near-infrared extinction map of the CMC. Analysis of the line properties were made through Gaussian fits to the line profiles. We present a statistical comparison of the line properties for sources in the CMC with a sample of 36 cores in Orion A from Tatematsu et al. and a larger sample of 150 intermediate and high-mass cores from Plume et al. We acknowledge the NSF for funding under Award No. AST-0847170, a PAARE Grant for the Calfornia-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE).

349.21 – **Ices and the Extinction Curve in the Quiescent Medium of Isolated Dense Cores**

Abraham C. A. Boogert[1], T. Huard[2], A. Cook[3], J. Chiar[4], C. Knez[2], L. Decin[5], G. Blake[1], X. Tielens[6], E. van Dishoeck[6]

[1]*California Institute of Tech.,* [2]*University of Maryland,* [3]*NASA/Ames,* [4]*SETI,* [5]*KU Leuven, Belgium,* [6]*Leiden Observatory, Netherlands.*
9:00 AM - 6:30 PM

For a sample of 31 stars behind isolated dense cores, ground-based and Spitzer spectra and photometry in the 1-25 um wavelength range are combined. We use this unique dataset to (1) investigate the composition of the ices before Young Stellar Objects (YSOs) are formed and (2) determine the 'high resolution' extinction curve.

We find that the strengths of the 6.0 and 6.85 um ice absorption bands are in line with those of YSOs. Thus, their carriers, which, besides H2O and CH3OH, may include NH4+, HCOOH, H2CO, and NH3, are readily formed in the dense core phase. The 3.53 um C-H stretching mode of solid CH3OH was discovered. The CH3OH/H2O abundance ratios of 5%-12% are larger than upper limits in the Taurus molecular cloud. The initial ice composition therefore depends on the environment. Signs of thermal and energetic processing that were found toward some YSOs are absent in the ices toward background stars.

Furthermore, the extinction curve is derived empirically from the 1-25 um spectra. Its high resolution allows for the separation of continuum and feature extinction. The extinction between 13 and 25 um is ~50% relative to that at 2.2 um. This probably indicates the presence of a population of large grains (R_V>=5.5). However, the peak optical depth of the 9.7 um band of silicates relative to the continuum extinction at 2.2 um is significantly shallower than in the diffuse ISM. This extends the results of Chiar et al. to a larger sample and higher extinctions.

349.22 – **Physical Properties of Galactic Star Forming Region W51**

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9:00 AM - 6:30 PM

The NRAO Green Bank Telescope (GBT) K-band Focal Plane Array (KFPA) was commissioned in 2011. The first commissioning observations with the KFPA yielded exciting discoveries of the properties of molecular clouds in our galaxy. We present observations of the ammonia (NH_3) (J,K) = (1,1), (2,2), (4,4), (5,5) and (6,6) inversion lines toward the molecular cloud W51 using the GBT. We report the first detection of maser emission in the (J,K) = (6,6) inversion transition. The integrated line intensity maps are used to compute physical temperatures of the region. We find that the active star formation in several regions within W51 is warming the environment and causing a wide range of temperatures and densities.

349.23 – **HI Maps of the Lockman Hole Region and a Comparison with Spitzer**

160 micron Maps

Bruce Grossan[1], C. Heiles[2], J. E. G. Peek[3]

[1]*University of California Space Sciences Laboratory,* [2]*University of California, Berkeley, Department of Astronomy,* [3]*Colombia University Department of Astronomy.*

9:00 AM - 6:30 PM

Previously, our collaboration acquired a Spitzer 160 um map of more than 14 contiguous sq. deg. in the Lockman Hole, one of the largest low-dust regions in the sky, and ideal for far-IR background studies. In order to understand the gas and dust in the region, we have now acquired HI velocity data cubes with the Green Bank Telescope covering 23 sq. deg. of this region. Here we present our new GBT maps, which show a rich variety of velocity-dependent structure. We also present multi-frequency analyses detailing the gas and dust in the region, one of the first studies probing the relation between these components in this very low-dust regime.

349.24 – **GALFA HI: Candidate Sites for H2 Formation in Cold HI Emission and Other Tracers**

Jonathan Newton[1], S. J. Gibson[1], K. A. Douglas[2], B. Koo[3], J. Kang[3], G. Park[3], J. E. G. Peek[4], E. J. Korpela[5], C. Heiles[6], T. M. Dame[7]

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9:00 AM - 6:30 PM

Interstellar gas has a variety of temperature phases, but only the coldest clouds are dense enough to collapse gravitationally and form stars. How do such clouds form? A key step in this process is the transition from neutral atomic hydrogen (HI) to molecular hydrogen (H2). To identify candidate sites where this HI-to-H2 transition may be underway, we have developed a method of fitting isolated HI 21cm emission features to constrain their spin temperature and other properties vs. position 21cm-line data cubes. Our method uses the Nelder-Meade `amoeba' method to solve the relevant radiative transfer equation by identifying the absolute chi-squared minimum in the parameter space. As other investigators have noted, this approach requires a very high signal-to-noise ratio, so we are using sensitive Arecibo L-band Feed Array (ALFA) observations, starting with narrow-line HI emission clouds in the inner-Galaxy ALFA (I-GALFA) survey, and we have also tested the reliability of our method with a large suite of model spectra. Cold HI clouds confirmed by the fit will be compared to tracers of molecular gas, including CO lines and FIR dust emission.

The I-GALFA survey is part of the Galactic ALFA HI data set obtained with the Arecibo 305m telescope. Arecibo Observatory is part of the National Astronomy and Ionosphere Center, operated sequentially by Cornell University and Stanford Research Institute under Cooperative Agreement with the U.S. National Science Foundation.

349.25 – **Water Maser Polarization in W3(OH)**

Steven Merriman[1], E. Momjian[2], A. Sarma[1]

[1]*Depaul University,* [2]*NRAO.*

9:00 AM - 6:30 PM

We present observations of 22GHz H_2O masers in the star forming region W3(OH) taken with the Very Long Baseline Array (VLBA) with the aim of measuring magnetic fields via the Zeeman effect. We observed two epochs spaced apart by six months. During the first epoch (5/2010), the masers were largely quiescent. During the second epoch (11/2010), there was significant flaring activity. Our goal is to compare the magnetic fields measured during the two epochs. So far, we have reduced the data from the flaring event, and detected 85 masers, located in 3 distinct groups; the morphology is consistent with previous observations. We intend to report the derived line of site magnetic field values of the H_2O masers and compare them with previous magnetic field measurements targeting the same source, or other, similar H_2O maser sources.

Funding for this poster presentation is being provided by the NRAO through the summer student program, of which Steven Merriman was a part.

349.26 – **Cm and mm Survey of Molecular Absorption Lines in Centaurus A**

Juergen Ott[1], S. Muller[2], D. Meier[3], A. Peck[1], V. Impellizzeri[1], F. Walter[4], C. Henkel[5], S. Martin[6], S. Aalto[2], P. van der Werf[7], I. Feain[8], C. Anderson[3]

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9:00 AM - 6:30 PM

We present Australia Telescope Array data of molecular absorption lines toward the bright central core of Centaurus A. The line of sight crosses the prominent dust lane and continues through the disk and eventually through gas that may be very close to the central supermassive black hole. The goal of our the survey is to determine the physical conditions of the gas via analyses of molecular line tracers including molecular abundances and excitation that is sensitive to changes in temperature, density, ionization, and shocks. This study allows us to derive the physical conditions of every absorption line complex and finally let us assign the most likely environments. We present ATCA data in the 20-50GHz range at medium resolution of a few km/s and possibly ALMA data at 3mm and 1mm wavelengths. The project continues with sub-km/s higher spectral resolution for the most important lines in 2012.

349.27 – **The Energy Budget of Massive Star-Formation in Andromeda**

Karin M. Sandstrom[1], B. Groves[1], M. Kapala[1], J. Dalcanton[2], K. Gordon[3], O. Krause[1], A. Leroy[4], H. Rix[1], E. Schinnerer[1], A. Schruba[1], G. van de Ven[1], F. Walter[1], D. Weisz[2]

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9:00 AM - 6:30 PM

M 31, the nearest massive galaxy, affords a unique opportunity to study the energy balance of the star−formation (SF) process on the spatial scales (<50 pc) of individual SF regions. For the 'heating terms', UV to near−IR data from the Pan−chromatic Hubble Andromeda Treasury (PHAT) provide a direct census of all young stars in M 31; for the 'cooling terms', we have compiled an unprecedented set of multi−wavelength data to trace the thermal state of ISM gas and dust across its multiple phases. This dataset includes far-IR and sub-mm broadband mapping across the whole disk of M 31 using the PACS and SPIRE instruments on Herschel to trace the dust spectral energy distribution; PACS spectroscopy in several regions of the key far-IR cooling lines--[CII] 158 µm and [OI] 63 µm --to trace the thermal state of neutral ISM gas; and fully-sampled optical integral-field spectroscopy from 3700-7100 Angstrom covering the same fields to probe the excitation and structure of ionized gas. The combination of these surveys will allow us to trace UV photons from their origin in massive stars through their various paths to heating ISM dust and gas. In this poster we present early results using the PACS and SPIRE photometry to study the heating of dust by different age stellar populations in the bulge and disk of M 31.

349.28 – **Dust Infrared Emission in an H2-Forming, Perseus-Arm Cloud**

Aaron C. Bell[1], S. J. Gibson[1], A. Noriega-Crespo[2], W. T. Reach[2], S. Carey[2], M. Miville-Deschenes[3], F. Boulanger[3], C. M. Brunt[4], A. R. Taylor[5], P. G. Martin[6], K. A. Douglas[7]

[1]*Western Kentucky University,* [2]*Infrared Processing and Analysis Center, Caltech,* [3]*Institut d'Astrophysique Spatiale, Universite Paris, France,* [4]*Exeter University, United Kingdom,* [5]*University of Calgary, Canada,* [6]*Canadian Institute for Theoretical Astrophysics, University of Toronto, Canada,* [7]*Dominion Radio Astrophysical Observatory, Canada.*

9:00 AM - 6:30 PM

An essential step in the formation of new stars is the condensation of ambient neutral atomic hydrogen (HI) into the molecular phase (H2). It is well known that molecular clouds collapse to form protostars, but less understood is how molecular clouds themselves begin to form. The process is difficult to study because the transition from HI to H2 is not very energetic, which limits direct observations. We study this process indirectly, by examining the interstellar dust within these H2-forming clouds. The dust is readily observed via infrared thermal emission. We use HIRES IRAS and Spitzer IRAC and MIPS imaging photometry to investigate a target cloud in the Perseus spiral arm in the which the HI-to-H2 transition appears to be underway, as evidenced by strong HI self-absorption, variable CO emission, and significant ``excess'' infrared emission. We have sampled the dust spectral energy distribution (SED) at many positions on and off this cloud in all IRAS and Spitzer photometric bands. We interpret these data by fitting the SEDs with the DustEM infrared emission model and infer the grain population composition and evolutionary status in this H2-forming cloud and others like it.

349.29 – **GALFA HI: The Inner-Galaxy ALFA (I-GALFA) Low-Latitude HI Survey**

Steven J. Gibson[1], B. Koo[2], K. A. Douglas[3], J. Kang[2], G. Park[2], J. E. G. Peek[4], E. J. Korpela[5], C. Heiles[6], J. H. Newton[1]

[1]*Western Kentucky University,* [2]*Seoul National University, Korea, Republic of,* [3]*Dominion Radio Astrophysical Observatory, Canada,* [4]*Columbia University,* [5]*Berkeley Space Sciences Laboratory,* [6]*University of California - Berkeley.*

9:00 AM - 6:30 PM

The Inner Galaxy ALFA (I-GALFA) survey presents a new, richly-detailed view of neutral atomic hydrogen (HI) gas in the Galactic disk. Using the Arecibo 305m radio

telescope and 7-beam ALFA receiver, we have mapped all HI 21cm line emission and absorption at Galactic longitudes 32 to 77 degrees and latitudes -10 to +10 degrees, with some extensions to 20-25 degrees off the plane. I-GALFA covers more than 1650 square degrees with a 4-arcminute beam and over 8 million observed spectra, using 0.184 km/s velocity channels covering LSR velocities from about -700 to +700 km/s. The brightness temperature RMS noise is 0.2 K in empty channels and 1 K in channels filled with bright emission. These combined parameters represent a breakthrough for studies of the diffuse interstellar medium in a wide range of environments. Newly-revealed features include finely-structured chimneys and worms in the disk-halo region, small and large expanding shells from ancient supernovae, intricate spiral structure in the far-side outer disk, and narrow-line cold HI emission and absorption in areas of molecular cloud formation. A public release of data is planned for January 2012. For more data access information and other details, please see http://www.naic.edu/~igalfa/.

The I-GALFA survey is one portion of the larger Galactic ALFA HI data set covering the entire sky between Declinations of -1 to +38 degrees visible with the Arecibo 305m telescope. Arecibo Observatory is part of the National Astronomy and Ionosphere Center, operated sequentially by Cornell University and Stanford Research Institute under Cooperative Agreement with the U.S. National Science Foundation.

349.30 – **Tracing the Serpens Molecular Cloud with 12CO and 13CO J = 2 -> 1: Achieving High Resolution over a Large Field of View.**

Kaylan Burleigh[1], A. Chromey[1], J. Bieging[1], C. Kulesa[1]

[1]*University of Arizona.*
9:00 AM - 6:30 PM

We made high resolution 2-D spectroscopic maps of ^{12}CO and ^{13}CO J = 2 -> 1 emission over about 1.1 deg^2 for the Serpens molecular cloud. We took our observations with the Submillimeter Telescope on Mt. Grahamn, Arizona, and achieved 38'' spatial and 0.3 km/sec spectral resolutions in both the ^{12}CO and ^{13}CO maps. These data allow us to trace the local temperature and velocity distribution of gas for the most active star forming regions in Serpens. We use a molecular cloud model and the spectral line information derived from our ^{12}CO and ^{13}CO maps to estimate the total hydrogen (H_2 and HI) column density at all spatially resolved pixels. Finally, we compare our hydrogen column density map to a well-known optical extinction map for Serpens, derived from *Spitzer* c2d Legacy project data, and the distribution of cold and dense gas in Serpens, which was previously measured using Bolocam at the Caltech Submillimeter Observatory. This research was supported in part by NSF Grant # AST-0708131 to the University of Arizona and the University of Arizona 2010-2011 Space Grant program.

349.31 – **IRAS01202+6133: A Possible Case of Protostellar Collapse Triggered by a Small HIIRegion**

Sung-Ju Kang[1], C. Kerton[1]

[1]*Iowa State University.*
9:00 AM - 6:30 PM

The molecular gas surrounding an HII region is thought to be a place where star formation can be induced. One of the main questions in the study of star formation is how protostars accrete material from their parent molecular clouds and observations of infall motions are needed to provide direct evidence for accretion. This poster will present an analysis of submm spectroscopic observations of the submm/infrared source IRAS 01202+6133 located on the periphery of the HII region KR 120. HCO+(J=3-2) spectra of this source show a classic blue-dominated double-peaked profile indicative of infall motions that would be expected to occur in the envelope surrounding a young protostellar object. The HCO+ spectrum toward the core was fitted using models incorporating both outflow and infall components along with basic assumptions regarding excitation temperature trends within molecular cloud cores. Using the models, we derive physical properties of the infall kinematics and the envelope structure.

350 – Astronomy in Middle & High Schools

Poster Session – Exhibit Hall – Wednesday, January 11, 2012, 9:00 AM - 6:30 PM

350.01 – **Incorporating Astronomy Research into the High School Curriculum**

Rachael Beaton[1], G. Zasowski[1], W. Dirienzo[1], J. Corby[1]

[1]*Univ. of Virginia.*
9:00 AM - 6:30 PM

Over the past three years, graduate students in the University of Virginia Astronomy Department (UVa) have partnered with the Central Virginia Governor's School for Science and Technology (CVGS) to advise high school juniors in individual astronomy research projects spanning eight months. CVGS, located 60 miles from UVa and servicing 14 schools in rural central VA, operates a daily, half-day program where talented high school juniors and seniors take courses in college-level science, mathematics, and technology, including research methods. UVa graduate students have mentored over a dozen students through astronomy research projects to fulfill their course requirements. The result of this unique partnership is the development of a full astronomy research curriculum that teaches the terminology, background concepts, analysis techniques and communication skills that are required for astronomy research, all designed for an off-site setting. The curriculum is organized into a set of "Tutorials," which when combined with the standard CVGS Research and Statistics courses, result in an an effective, comprehensive, and productive research collaboration. In this poster, we will display our curriculum in a step by step basis as a model for potential collaborations with other institutions and comment on how these opportunities have benefited the high school students, CVGS and the graduate students involved.

350.02 – **The Georgians Experience Astronomy Research in Schools (GEARS) High School Galaxy Unit**

Sarah Higdon[1], J. Higdon[1], J. Aguilar[2]

[1]*Georgia Southern Univ.,* [2]*Georgia Department of Education.*
9:00 AM - 6:30 PM

The Georgians Experience Astronomy Research in Schools (GEARS) project aims to provide a rigorous and inquiry-based astronomy curriculum to GA's public schools. Exposure to data mining and research activities using the astronomy archives can be the trigger for the next generation of scientists, and it improves a student's ability to solve problems. Students then consolidate their findings and improve their communication skills by writing scientific reports and creating video presentations. The GEARS curriculum has units on the solar system, life in the Universe, stars, galaxies and cosmology. Here we present some of the activities in the Galaxy Unit. The GEARS material is freely available. Please email shigdon_AT_georgiasouthern.edu if you would like more details. NASA Grant NNX09AH83A through the GADOE funds this project.

350.03 – **The Effect of an Authentic Science Research Experience on Teachers and Students through NITARP**

Marcella Linahan[1], L. M. Rebull[2], C. H. Johnson[3], J. C. Gibbs[4], D. C. Sartore[5], A. Rameswaram[1], H. N. Sprow[1], J. R. Fagan[1], A. Pullinger[1], N. J. Ezyk[1], T. Nuthmann[4], T. Canakapalli[4], S. Aryal[4], M. Nishida[4], N. G. Killingstad[3], T. S. McCanna[3], A. M. O'Bryan[3], S. D. Carlson[3], M. L. Clark[3], S. M. Koop[3], T. A. Ravelomanantsoa[3], C. M. Tilley[5], K. S. Badura[5]

[1]*Carmel Catholic High School (Mundelein, IL),* [2]*Spitzer Science Center/CalTech (Pasadena, CA),* [3]*Breck School (Minneapolis, MN),* [4]*Glencoe High School (Hillsboro, OR),* [5]*Pine Ridge High School (Deltona, FL).*
9:00 AM - 6:30 PM

As part of the NASA/IPAC Teacher Archive Research Project program (NITARP), four high school teachers have participated with selected students in a research project using archival Spitzer data to search for young stellar objects in two bright-rimmed clouds: BRC 27 and BRC 34. Our scientific research findings are presented in another poster, Johnson et al. A key initiative in science education is integrating authentic scientific research into the curriculum. Since the NITARP program funds a limited number of teachers and students, our group has investigated the role of team leaders (both teachers and students) in educating and inspiring other teachers and students. This project allows our students to assume an active role in the process of project development, teamwork, data collection and analysis, interpretation of results, and formal scientific presentations. This poster presents our observations on methods used by student team leaders in disseminating the information to other students within the school, as well as to other local schools and interest groups. Since three of the four teachers on our team are female, we have also looked at how these teachers inspire young women to participate in this program and to pursue STEM (Science, Technology, Engineering, and Math) careers. This program was made possible through the NASA/IPAC Teacher Archive Research Project program (NITARP) and was funded by NASA Astrophysics Data Program and Archive Outreach funds.

350.04 – **Teacher-Student Education and Public Outreach Using Spitzer Data**

Adam Keeton[1], S. Mehta[2], M. Butler[3], T. Spuck[4], M. Heller[5], W. Sixel[1], C. Cook[2], P. Hutchinson[2], M. Butler[6], M. Abajian[7], V. Gorjian[8]

[1]*North High School,* [2]*Haddam- Killingworth High School,* [3]*Orange County Astronomers,* [4]*Oil City High School,* [5]*Clarion University,* [6]*Tuscarora High School,* [7]*Infrared Processing & Analysis Center/California Institute of Technology,* [8]*JPL/Caltech.*
9:00 AM - 6:30 PM

As part of the NASA-IPAC Teacher Archival Research Program (NITARP) astronomers, teachers, and students collaborated in using archival data from the Spitzer Space Telescope to identify galaxy clusters around Active Galactic Nuclei (AGN) at a high redshift of $z \approx 1$. The team analyzed 168 fields around AGN to determine if an over

density of sources existed. The team, including members from across the US, initially explored the idea at the 2011 Winter AAS Meeting. The initial meeting followed up with regular conference calls, and a 4-day face to face meeting at the Spitzer Science Center in Pasadena, CA. Throughout the process teachers and students gained a great deal of knowledge and experiences conducting authentic science research, and scientists gained a deeper understanding of education issues. The poster will present the processes used to engage students in this real-world experience, and the many benefits to all. In addition our team will present inquiry based activities using archival data from the Spitzer Space Telescope, APT photometry software, and an Excel spreadsheet template, to enrich their understanding of the structure of the universe. NITARP is a NASA funded program.

350.05 – **The James Webb STEM Innovation Project: Bringing JWST to the Education Community**

Bonnie Eisenhamer[1], J. Harris[1], H. Ryer[1], J. Taylor[1], M. Bishop[1]

[1]*STScI.*

9:00 AM - 6:30 PM

Building awareness of a NASA mission prior to launch and connecting that mission to the education community can be challenging. In order to address this challenge, the Space Telescope Science Institute's Office of Public Outreach has developed the James Webb STEM innovation Project (SIP) - an interdisciplinary project that focuses on the engineering aspects and potential scientific discoveries of JWST, while incorporating elements of project-based learning. Students in participating schools will use skills from multiple subject areas to research an aspect of the JWST's design or potential science and create models, illustrated essays, or technology-based projects to demonstrate their learning. Student projects will be showcased during special events at select venues in the project states - thus allowing parents and community members to also be benefactors of the project. Currently, the SIP is being piloted in New York, California, and Maryland. In addition, we will be implementing the SIP in partnership with NASA Explorer Schools in the states of New Mexico, Michigan, Texas, Tennessee, and Iowa.

350.06 – **Bringing Astronomy Activities and Science Content to Girls Locally and Nationally: A Girl Scout and NIRCam Collaboration**

Larry A. Lebofsky[1], M. L. Higgins[1], D. W. McCarthy[2], N. R. Lebofsky[1]

[1]*Girl Scouts of Southern Arizona Sahuaro,* [2]*Steward Observatory, University of Arizona.*

9:00 AM - 6:30 PM

In 2003, the University of Arizona's (UA) NIRCam E/PO team (NASA James Webb Space Telescope) and the Sahuaro Girl Scout Council began a long-term collaboration to bring astronomy activities and concepts to Girl Scout leaders, staff, and volunteers and, in turn, to their councils and girls, i.e., to train the trainers. Nationally, our goal is to reach leaders in all councils. To date, this program has reached nearly 200 adults from 39 councils nationwide (plus Guam and Korea), bringing together leaders, UA graduate students, and NIRCam scientists and educators to experience Arizona's dark skies. Locally, our goal is to provide Science, Technology, Engineering, and Math (STEM) education to girls of all ages throughout southern Arizona. To accomplish this in astronomy, we have additional ongoing collaborations with the Planetary Science Institute, the National Optical Astronomy Observatory, and, most recently with the Amphitheater School District. One of the programs that we have been recently emphasizing is Family Science and Astronomy Nights. These programs can be run at our local Girl Scout facility or can be incorporated into programs that we are running in local schools. Our near-term goal is to provide a series of interconnected activities that can be done in classrooms, in afterschool programs, as part of the Family Science and Astronomy Nights, or in summer astronomy camps. Our long-term goal is to empower girls ultimately to become leaders who are excited about the night sky and can take lead roles presenting activities and facilitating astronomy nights. Our poster will display a variety of the activities we have refined and developed through this progam: scale models of the Solar System and beyond, classifying Solar System objects, a portable human orrery, observing the night sky with and without telescopes, constellation transformations, and constellation sorting cards.NIRCam E/PO website: http://zeus.as.arizona.edu/~dmccarthy/GSUSA

350.07 – **Novel Low-Cost Technologies for Communicating Astronomical Topics**

Jacob Noel-Storr[1], B. N. Cole[1], D. C. Lierheimer[1], RIT Insight Lab

[1]*Rochester Inst. Of Technology.*

9:00 AM - 6:30 PM

We are committed to the development of educational technology tools that are designed with cost and "user-tinkerability" in mind. We strive to increase the potential for technology-rich access to scientific data to be in the hands of a much larger slice of the educational community. Here we present three low cost educational technology tools developed by a diverse team including many undergraduate and high school students. The tools we present are the Planeterrainium -- A digital interactive floor projection system allowing users to explore planetary surfaces in 3D; the Digital Solar Explorer -- a 5 foot inflatable sphere designed to allow for the exploration of solar imagery; and the Scube -- a digital immersive tentware system. In addition to the system development, we describe projects that involve both undergraduate and high school students in the development of content for these systems, encouraging the growth of both scientific and technological literacy in the process.

Funding for this work was provided in part by education supplements to NASA contracts NNX08AO03G and NNX07AM68G, and by the RIT Provost's Office and Chester F. Carlson Center for Imaging Science.

350.08 – **Solar Filters, Galileoscopes and Students: Analysis of Two Curricula and Attitudes Toward Science**

Erika Grundstrom[1]

[1]*Vanderbilt University and Fisk University.*

9:00 AM - 6:30 PM

One of the lasting legacies of the International Year of Astronomy in 2009 is the Galileoscope. People around the world have one, but there is a major astronomical object they aren't supposed to look at - the Sun! But in order to facilitate observations during the actual school day, one best incorporate the Sun. We report on a project to build and use solar filters for the Galileoscope, incorporate them into the standard daytime classroom, and measure attitudes toward science.

We describe the solar filters and construction thereof (best done beforehand), use of Galileoscopes by students, and the joining of the two worlds. We have developed two curricula - one more-mathematics intensive and one less-mathematics intensive (suitable for advanced students and for middle-school students respectively) which we will describe. We will also describe some trials and tribulations that may be encountered (such as actually finding the Sun, personnel management, lack of sunspots, clouds, amount of time devoted to the observations, varying equipment abilities, etc.). Measurements of attitudes toward science show an increase in favorableness toward science and an increase of feeling like a scientist through this curriculum.

We acknowledge a SEED grant from the Astronomical Society of the Pacific and that this work is supported in part by the Vanderbilt University Learning Sciences Institute (LSI).

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301 – The Solar System & Extrasolar Habitable Zones

Oral Session – Room 12A – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

301.01 – **Chemistry of the Moon-Forming Impact**

Bruce Fegley[1], L. Schaefer[2], K. Lodders[1]

[1]*Washington Univ.,* [2]*Harvard University.*

10:00 AM - 10:10 AM

We model chemistry of the Moon-forming impact using chemical equilibrium, and where relevant, chemical kinetic calculations. We present results as a function of T and P for the average composition of the Earth plus Moon. Some results are (1) molecular and monatomic oxygen are important gases, and thus the post-impact silicate vapor atmosphere is significantly more oxidizing than the hydrogen-rich solar nebula, (2) SiO is the major Si-bearing gas over a large P-T range, (3) the "condensation" chemistry and volatility sequence is significantly different than in the solar nebula, and (4) tungsten (and other "refractory" metals) become much more volatile in the silicate vapor atmosphere than in the solar nebula because W reacts with oxygen forming W oxide gases. We discuss some implications for astronomical observations of similar impacts in other solar systems and for lunar and terrestrial geochemistry. We acknowledge support from the NSF Astronomy Program and from NASA.

301.02D – **Observations and Models of Iapetus's Microwave Emissivity**

Paul Ries[1]

[1]*University of Virginia.*

10:10 AM - 10:30 AM

Iapetus is one of the most unusual moons in the solar system and is best known for its stark hemispherical albedo contrast at optical wavelengths. However, only a handful of previous observations have explored whether this contrast also manifests itself in the thermal emission. While Iapetus's daytime infrared brightness temperature only varies by about 10K, our observations with the Green Bank Telescope (GBT) have shown that Iapetus's microwave brightness temperature at the Ka-Band (26-40 GHz) can vary by as much as 60K, with effective emissivities dropping to less than 0.3 on the bright trailing hemisphere. We have also observed that the variation is substantially less at 3.3 mm. This behavior is unprecedented in the astronomical literature, but not entirely unprecedented in the literature from the remote sensing branch of climate science. Climate scientists have made extensive studies of Earth's microwave emissivities from 10 to 200 GHz and found similarly shaped features in dry snowpacks and glaciers. Here we present an attempt to model Iapetus's microwave emissivity using various snow

models from the climate science literature and report on the final observations from a GBT observing campaign.

This research has been supported by the NRAO pre-doc program and the Virginia Space Grant Consortium graduate fellowship program.

301.03 – **Searching the Southern Skies with the La Silla-QUEST KBO Survey: Probing the Inventory of Large and High Inclination Kuiper belt**

Megan E. Schwamb[1], D. L. Rabinowitz[1], S. Tourtellotte[1], R. Brasser[2]

[1]*Yale University,* [2]*Academia Sinica Institute of Astronomy and Astrophysics, Taiwan.*

10:30 AM - 10:40 AM

Although telescopes from the Northern hemisphere can reach declinations as south as -25 degrees, the Southern hemisphere has to date remained virtually unexplored for the largest Kuiper belt objects (KBOs), with potentially 1-2 new dwarf planet-sized bodies awaiting discovery. In order to find the largest and brightest members of the Kuiper belt, we are engaged in a three-year observational campaign to survey the southern skies using the robotized ESO 1.0-m Schmidt Telescope located at La Silla Observatory in Chile equipped with the QUEST large-area CCD camera, with an effective field of view of 8.3 square degrees. We have surveyed ~10,000 square degrees south of the ecliptic to a depth of R magnitude ~21.5. We present the detections from the La Silla-QUEST survey and estimates for the number of dwarf planets residing in the outer solar system and remain to be discovered.

With the majority of our sky coverage, south of -20 degrees ecliptic latitude, our survey is sensitive to extreme inclination orbits. The discovery of 2008 KV42, (by Gladman et al.) with a perihelion near Uranus and an extreme (nearly perpendicular) inclination of 104 degrees, suggests a population of bodies on similar orbits with high inclinations compared to typical KBOs and Centaurs. These objects are metastable gravitationally scattering off of Uranus and Neptune with lifetimes of hundreds of million years, suggesting there must be a source population feeding this unstable reservoir. In our survey, we have found a new member of this high-inclination population, 2010 WG9 with an inclination of 70 degrees and a perihelion of 18.7 AU. We discuss the implications and origins for a population of high-inclination orbits in the Kuiper belt, placing constraints on the size and distribution of such a population.

Acknowledgements: MES is supported by a NSF Astronomy and Astrophysics Postdoctoral Fellowship under award AST-1003258.

301.04 – **The Habitable Zone Gallery**

Dawn M. Gelino[1], S. R. Kane[1]

[1]*NASA Exoplanet Science Institute, Caltech.*

10:40 AM - 10:50 AM

The Habitable Zone Gallery (www.hzgallery.org) is a new service to the exoplanet community which provides Habitable Zone (HZ) information for each of the exoplanetary systems with known planetary orbital parameters. The service includes a sortable table with information on the percentage of orbital phase spent within the HZ, planetary effective temperatures, and other basic planetary properties. In addition to the table, we also plot the period and eccentricity of the planets with respect to their time spent in the HZ. We provide a gallery of known systems which plot the orbits and the location of the HZ with respect to those orbits. Here we announce an upgrade to the service which includes improved planetary models, orbital movies, and various other features.

301.05 – **Super-earths - Atmospheres And Conditions For Life**

Lisa Kaltenegger[1]

[1]*MPIA/CfA, Germany.*

10:50 AM - 11:00 AM

A decade of exoplanet search has led to surprising discoveries, from giant planets close to their star, to planets orbiting two stars, all the way to the first extremely hot, rocky worlds with potentially permanent lava on their surfaces due to the star's proximity. Observation techniques have now reached the sensitivity to explore the chemical composition of the atmospheres as well as physical structure of some detected planets and find planets of less than 10 Earth masses (so called Super-Earths), among them some that may potentially be habitable.

Two confirmed non-transiting planets and several transiting Kepler planetary candidates orbit in the Habitable Zone of their host star. Observing mass and radius alone can not break the degeneracy of a planet's nature due to the effect of an extended atmosphere that can also block the stellar light and increase the observed planetary radius significantly. Even if a unique solution would exist, planets with similar density, like Earth and Venus, present very different planetary environments in terms of habitable conditions. Therefore the question refocusses on atmospheric features to characterize a planetary environment. We will discuss observational features of rocky planets in the HZ of their stars that can be used to examine if our concept of habitability is correct and how we can find the first habitable new worlds in the sky.

L.K. acknowledges support from NAI and DFG funding ENP Ka 3142/1-1.

302 – Molecular Clouds, HII Regions, Interstellar Medium

Oral Session – Room 16A – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

302.01 – **Water Absorption In The Milky Way: Herschel/hifi Insights On The History Of The Gas**

Nicolas Flagey[1], P. F. Goldsmith[1], D. C. Lis[2], PRISMAS Team

[1]*Jet Propulsion Laboratory,* [2]*CalTech.*

10:00 AM - 10:10 AM

The water molecule plays an essential role in the chemistry and physics of the dense regions of the interstellar medium (ISM). In particular, it is an important reservoir of oxygen and cooling agent. It is found in vapor or condensed in iced mantle on grains in the ISM. One specificity of the water molecule is due to its asymmetry. A molecule of water, at a given energy level, as defined by its quantum numbers, can either be ortho or para. The ratio between the population of ortho and para water is 3 in the high temperature limit. At lower temperature, the ortho/para ratio can be lower than 2. Collisions and interaction between the molecule and the grain are processes that may affect the ortho/para ratio. Consequently, measurements of the ortho/para ratio in water can provide insights on the history of the molecule and its environment.

The Herschel Guaranteed Time Key Progamme PRISMAS (P.I. M.Gerin) observed 25 molecules, including the five lower transitions of water, towards eight sources with strong dust emission in the Galactic plane with the HIFI instrument. We present the multiple absorption features of water due to foreground clouds that are known to intersect those lines of sight. We model the observations, taking into account background emission due to the continuum sources. We then infer optical depth along the line of sight and the ratio between ortho and para water column densities. We discuss the results and their implications on our understanding of physical and chemical processes.

302.02 – **The Carbon Chronometer for Molecular Cloud Ages**

Paul Goldsmith[1]

[1]*JPL.*

10:10 AM - 10:20 AM

The steady state structure of interstellar material illuminated by the pervasive external radiation field includes successive layers in which carbon is in the form of C+, C0, and CO as the extinction increases. However, this structure takes a significant time to evolve from an initial configuration characteristic of a diffuse cloud in which the carbon is primarily ionized. The timescale for the transformation to the state in which the neutral carbon layer has much reduced column density compared to earlier times is quite substsantial due to the low densities characteristic of the outer portion of clouds. Accurate measurements of this carbon skin would, in principle, allow a determination of the time that has elapsed since the cloud started its evolution to a denser, higher extinction object. This time scale will be an important complement to other chemical time scales that we can use to determine the lifetime of molecular clouds.

302.03D – **The Role of Radiation Feedback in Starburst Environments**

Sherry Yeh[1], C. D. Matzner[1], E. R. Seaquist[1]

[1]*University of Toronto, Canada.*

10:20 AM - 10:40 AM

Massive bursts of stellar activity in starburst environments feed prodigious amount of energy and momentum into the surrounding neutral clouds. With sufficiently intense irradiation from starbursts, the structure of an HII region will be dominated by radiation pressure rather than ionized gas pressure, and radiative energy input in photodissociation regions (PDRs) becomes more important. This state is of considerable interest because of its role in the formation of massive stars, the disruption of giant molecular clouds, and the evolution of starburst galaxies. We study the role of radiation feedback in starburst environments via both theoretical and observational approaches. We argue that radiation pressure is the underlying mechanism for the remarkable constancy of ionization parameters in starburst environments. We also point out that clumping in the neutral material and compression by stellar wind pressure can act to reduce ionization parameters. We use the Cloudy code to determine effective ionization parameters for a population of static dusty HII regions compressed by both radiation pressure and stellar winds. We conclude that the inner starburst region of M82 and the Antennae Galaxies HII regions are both dominated by a combination of radiation pressure and shocked winds. We investigate radiative energy feedback in starburst environments by observing the nearest starburst region 30 Doradus in the LMC. We observe 30 Doradus using NOAO Extremely Wide-Field Infrared Imager (NEWFIRM) with H_2 1-0 S(1), Brγ, and [FeII] lines. While H_2 can be either radiative or shock excited, the near infrared [FeII] emission line traces shock activities, and the hydrogen recombination line Brγ arises from regions ionized by UV radiation. Therefore ratios of the three emission lines form very useful diagnostics to assess the fraction of radiative and shock feedback. We preliminarily suggest that radiative energy input in the 30 Doradus PDRs is non-negligible.

302.04 – **Abundance Patterns of Neutron-Capture Elements in the Interstellar Medium**

Adam M. Ritchey[1], S. R. Federman[2], D. L. Lambert[3]

[1]*University of Washington,* [2]*University of Toledo,* [3]*University of Texas at Austin.*

10:40 AM - 10:50 AM

We present the results of an archival survey of neutron-capture elements in diffuse interstellar clouds from HST/STIS observations of over 50 Galactic sight lines. Existing measurements of the interstellar abundances of Kr, Rb, Cd, and Sn have indicated deficiencies in our understanding of the production of elements beyond the iron peak via slow and rapid neutron-capture processes. The elements Kr and Rb, which are primarily synthesized by massive stars through the weak s-process and the r-process, are found to be underabundant in interstellar gas compared to expectations based on current knowledge of dust depletion. At the same time, Cd and Sn, which are produced in larger part by the main s-process in low-mass AGB stars, exhibit less depletion than expected. By combining new abundance determinations for As, Cd, Sn, and Pb with recent surveys of Ga, Ge, Kr, and Rb, our study seeks to reveal the causes of the inferred deficit in the contribution from massive stars to the abundances of neutron-capture elements in the current epoch. We find that while Ga, Ge, and Pb follow normal depletion patterns, As is significantly overabundant, with an overall depletion level similar to Sn. Yet, unlike Sn, As is almost entirely a product of massive-star nucleosynthesis. The ultimate resolution of these discrepancies will likely involve a deeper understanding of dust grain depletion than presently exists.

This research was funded by the Space Telescope Science Institute through grant HST-AR-12123.

302.05D – **Recalibration of Pagel's Strong-Line Method to Determine Abundances Considering Thermal Inhomogeneities**

Maria Angeles Pena-Guerrero[1], A. Peimbert[1], M. Peimbert[1]

[1]*IA - UNAM, Mexico.*

10:50 AM - 11:10 AM

In this dissertation talk I present a recalibration of the low metallicity branch of Pagel's strong-line method. Pagel's method is used to determine oxygen abundances in far away HII regions ($0<z<1$) or HII regions with low intrinsic brightness. A recalibration is needed due to the systematic difference of at least 2000 K between Te[OIII] and Te(Bac); both temperatures represent the same zone in high ionization nebulae. This temperature difference implies the presence of important temperature inhomogeneities, t^2; which in turn imply higher abundances by a factor of about 2 (0.15-0.35 dex in the oxygen abundance, depending on the specific characteristics of each photoionized region). Additionally, the fraction of O depleted into dust grains is usually neglected in the calibrations of the literature (~0.10 dex in the oxygen abundance). We find that the total correction amounts to an increase in the O/H ratio of factors of 1.8-2.8 or 0.25-0.45 dex. This result has important implications in various areas of astrophysics such as the primordial helium determination, the study of the higher end of the IMF and the SFR, and the mass-luminosity function of galaxies, among others.

302.06 – **On The Ionization Of Luminous WMAP Sources In The Galaxy : Constrains From He Recombination Line Observations With The GBT**

D. Anish Roshi[1], A. Plunkett[2], V. Rosero[3], S. Vaddi[4]

[1]*National Radio Astronomy Observatory,* [2]*Yale University,* [3]*New Mexico Tech,* [4]*Rochester Institute of Technology.*

11:10 AM - 11:20 AM

The WMAP maximum entropy method foreground emission map is recently used to identify diffuse free-free emission sources in the Galaxy (Rahman & Murray 2010). It has been found that 18 most luminous WMAP sources produce more than half the total ionizing luminosity of the Galaxy. We observed radio recombination lines (RRLs) toward the luminous WMAP source G49 with the GBT near 1.4 GHz. Hydrogen and carbon RRLs are detected toward the source (G49.75-0.45) but no helium line is detected. The upper limit on He line implies that $(n_{He^+}/n_{He})/(n_{H^+}/n_H) < 0.24$, which puts severe constraint on the spectrum of the ionizing sources. The ionization requirement of the WMAP sources is more than half of that can be accounted from all the radio HII regions within these regions. Murray & Rahman (2010) propose that the additional ionization is due to massive clusters ($M > 10^4$ M_{sun}) embedded in the WMAP sources. For a standard IMF, the bulk of the ionizing flux from the cluster is due to stars of mass ~ 40 M_{sun}. Thus these clusters should produce enough photons with energy $\geq$ 24.6 eV to fully ionize helium in the diffuse regions. Our observations rule out a standard HII region picture with such massive clusters ionizing these sources. We discuss possibilities to produce `softer' spectrum for the sources ionizing the diffuse regions, which include (a) modification of the spectrum due to the diffusion of photons through clumpy ISM and (b) hot low-mass evolved stars as the source of ionization.

302.07 – **The Structure of NGC 1976 in the Radio Range**

Thomas L. Wilson[1], S. Casassus[2], K. M. Chynoweth[3]

[1]*US Naval Research Laboratory,* [2]*Departmento de Astronomia, Universidad de Chile, Santiago, Chile,* [3]*National Research Council Postdoctoral Research Associate at the US Naval Research Laboratory.*

11:20 AM - 11:30 AM

High angular resolution radio continuum images of NGC 1976 (M42, Orion A) at a frequency 330 MHz (wavelength 91 cm), 1.5 GHz (20 cm) and 10.6 GHz (2.8 cm), have been aligned, placed on a common grid, smoothed to common resolutions of 80" (=0.16 pc at 420 pc) and 90" (=0.18 pc) and compared on a position-by-position basis. The results are not consistent with a single value of electron temperature T_e. Rather, there is a significant variation, from T_e =6000K in the low intensity, extended region to T_e=8500K in the higher intensity, more compact region. The best fit to the data is a multi-layer model obtained from radio recombination line (RRL) data. An estimate of temperature fluctuations from the model yields t^2=0.003. This is a factor of 10 lower than fluctuation values from optical O^{++} line data.

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303 – A Sampling of Herschel's Key Programs: Views of the Milky Way and its Nearby Environs

Special Session – Ballroom F – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

Launched to L2 in May 2010, the European Space Agency's Herschel Space Observatory is designed to explore the far-IR and sub-mm spectral range (60 to 650 μm) with a 3.5 m telescope and three cryogenically cooled science instruments built by multinational consortia, with enabling contributions from NASA. This proposed Special Session will present Key Program science to the broad astronomical community gathered in Austin. The talks focus mainly on Galactic science. We are making this request for a Special Session on behalf of the US-based Herschel community via the NASA Hershel Science Center (NHSC; Latter and Appleton), and the NHSC Users Panel (Meixner).

303.01 – **Herschel in Mid-Mission: Status and Highlights**

George Helou[1]

[1]*Caltech.*

10:00 AM - 10:15 AM

In January 2012, Herschel will be roughly two thirds of the way into its science mission. Herschel has already contributed many striking results, and will still have more than a year of observing to complete. The status of the mission and its capabilities will be summarized, and some recent science highlights complementing the Key Program presentations will be shown. Resources available to the US community in support of

Herschel science will be pointed out.

This work is supported by NASA.

303.02 – **HIGGS: The Herschel Inner Galaxy Gas Survey**

Christopher L. Martin[1], HIGGS Team

[1]*Oberlin College.*

10:15 AM - 10:30 AM

The Herschel Inner Galaxy Gas Survey (HIGGS) is a Herschel Key Project to use the HIFI and PACS instruments to observe [CII], [NII], [OI], [OIII], and high-J CO emission lines in focused regions near the Galactic Center. By separating and evaluating the distinctly different roles of the central nuclear engine, the Galactic Bar, and dynamical stellar and interstellar feedback mechanisms, HIGGS is providing a high-resolution template for the physical processes in galactic nuclei throughout the local universe, in particular those engaged in starburst activity.

As the satellite continues to collect data in our survey regions, our team has continued to be impressed by the quality of Herschel data and the surprises to be found in the bands that it has made accessible.

303.03 – **HERschel Inventory of The Agents of Galaxy Evolution (HERITAGE) in the Magellanic Clouds**

Margaret Meixner[1]

[1]*STScI.*

10:30 AM - 10:45 AM

We are conducting a uniform survey of the Large Magellanic Cloud (LMC, 8×8.5 degrees), Small Magellanic Cloud (SMC, 5×5 degrees), and the Magellanic bridge (4×3 degrees) in SPIRE 250, 350, 500 um and PACS 100 and 160 um bands in order to produce a HERschel Inventory of The Agents of Galaxy Evolution (HERITAGE), the interstellar medium (ISM) and massive stars. The life cycle of baryonic matter in a galaxy is driven by the exchange of material between the ISM and stars. Dust is present at these key transition phases of matter: in the ISM, in the circumstellar environments of newly forming stars and in stellar ejecta of dying stars. The Herschel HERITAGE images are providing 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 (YSOs), and the dust ejected over the lifetime of massive stars. The ISM dust map will directly measure dust on a scale size of individual regions (~10pc, ~5-20 K) with column densities >0.85×10^{21} and >6×10^{21} H-atoms cm^{-2} for the LMC and SMC, respectively. Dust emission per beam will be detected for regions with >0.1 Msun at ~25 K, >5 Msun of 10 K. HERITAGE will complete 1) the census of massive YSOs down to >4 Msun Class 0 sources and 2) the inventory of dust injected into the ISM by massive evolved stars and supernova remnants (SNRs). HERITAGE will create an archival data set that promises a lasting legacy to match current LMC and SMC surveys at other wavelengths. In this talk, I will review the highlights from HERITAGE's first two years of results.

303.04 – **GOT C+: Galactic Plane Survey of the 1.9 THz [CII] Line**

William Langer[1]

[1]*JPL.*

10:45 AM - 11:00 AM

The ionized carbon [CII] 1.9 THz fine structure line is a major gas coolant in the interstellar medium (ISM) and controls the thermal conditions in diffuse gas clouds and Photodissociation Regions (PDRs). The [CII] line is also an important tracer of the atomic gas and atomic to molecular transition in diffuse clouds throughout the Galaxy. I will review some of the results from the recently completed Galactic Observations of Terahertz C+ (GOT C+) survey. This Herschel Open Time Key Project is a sparse, but uniform volume sample survey of [CII] line emission throughout the Galactic disk using the HIFI heterodyne receiver. HIFI observations, with their high spectral resolution, isolate and locate individual clouds in the Galaxy and provide excitation information on the gas. I will present [CII] position-velocity maps that reveal the distribution and motion of the clouds in the inner Galaxy and discuss results on the physical properties of the gas using spectral observations of [CII] and ancillary HI and 12CO, 13CO, and C18O J=1-0 data. The [CII] emission is also a useful tracer of the "Dark H2 Gas", and I will discuss its distribution in a sample of interstellar clouds. This research was conducted at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration.

303.05 – **Herschel Studies of the Evolution and Environs of Young Stars in the DIGIT, WISH, and FOOSH Programs**

Joel D. Green[1], DIGIT (OT) Key Project Team, WISH (GT) Key Project Team, FOOSH (OT1) Team

[1]*University of Texas at Austin.*

11:00 AM - 11:15 AM

The Herschel Space Observatory has enabled us to probe the physical conditions of outer disks, envelopes, and outflows of young stellar objects, including embedded objects, Herbig Ae/Be disks, and T Tauri disks. We will report on results from three projects, DIGIT, WISH, and FOOSH. The DIGIT (Dust, Ice, and Gas in Time) program (PI: Neal Evans) utilizes the full spectral range of the PACS instrument to explore simultaneously the solid and gas-phase chemistry around sources in all of these stages. WISH (Water in Star Forming Regions with Herschel, PI Ewine van Dishoeck) focuses on observations of key lines with HIFI and line scans of selected spectral regions with PACS. FOOSH (FU Orionis Objects Surveyed with Herschel, PI Joel Green) studies FU Orionis objects with full range PACS and SPIRE scans. DIGIT includes examples of low luminosity protostars, while FOOSH studies the high luminosity objects during outburst states. Rotational ladders of highly excited CO and OH emission are detected in both disks and protostars. The highly excited lines are more commonly seen in the embedded phases, where there appear to be two temperature components. Intriguingly, water is frequently detected in spectra of embedded sources, but not in the disk spectra. In addition to gas features, we explore the extent of the newly detected 69 um forsterite dust feature in both T Tauri and Herbig Ae/Be stars. When analyzed along with the Spitzer-detected dust features, these provide constraints on a population of colder crystalline material. We will present some models of individual sources, as well as some broad statistics of the emission from these stages of star and planet formation.

303.06 – **The Herschel Infrared Galactic Plane Survey: Hi-GAL**

John Bally[1]

[1]*Univ. of Colorado.*

11:15 AM - 11:30 AM

The **H**erschel ***infrared*** **GAL**actic Plane Survey has been granted time to observe 480 square degrees of the Galactic Plane with the PACS and SPIRE on-board the 3.5 meter Herschel Space Observatory in five bands; 70, 160, 250, 350, and 500 μm. The original Hi-GAL Open Time Key Project observed 240 square-degrees in the inner Galaxy from $l = -60^{o}$ to $+60^{o}$, $b = -1^{o}$ to $+1^{o}$. This portion of the survey includes the Central Molecular Zone surrounding the Galactic center and the Molecular Ring in the inner Galaxy. During Open Time 1 (OT1), time was granted to observe an additional 240 square degrees in the outer Galaxy from $l = 120^{o}$ to 240^{o}. Hi-GAL240 provides a high-resolution view of the closest portion of the Perseus Arm in the outer Galaxy and the anti-center region. A proposal has been submitted to complete coverage of the entire Galactic Plane in OT2. Hi-GAL provides a sensitive, high-resolution (5" to 35") view of the far-infrared and sub-mm dust-continuum from dense clumps, filaments, and clouds, highly embedded proto-stars, HII regions, FUV-heated bubbles, post-main sequence objects, and the diffuse ISM along the Galactic Plane. Hi-GAL data is being used to map the dust temperature and column density distribution in the Galaxy, to identify the most embedded proto-stars and proto-clusters, to measure the properties of dust emitting structures in all stages of their evolution as function of location and environment, and to probe the Galactic ecology - the cycling of gas from the ISM into stars and back into the ISM. Hi-GAL will serve as a template for the interpretation of far-infrared and sub-mm continuum emission from galaxies in the near and distant Universe where individual star forming complexes and dust structures can not be resolved. I will review some highlights and key results provided by Hi-GAL.

304 – Intergalactic Medium, QSO Absorption Line Systems

Oral Session – Room 16B – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

304.01 – **Signal Extraction for Sky-averaged 21-cm Experiments**

Geraint Harker[1], J. Pritchard[2], J. Burns[1], J. Bowman[3]

[1]*University of Colorado,* [2]*Imperial College London, United Kingdom,* [3]*Arizona State University.*

10:00 AM - 10:10 AM

The highly redshifted 21-cm line of hydrogen promises to be an excellent probe of the cosmic dawn (when the first stars ignited) and the epoch of reionization. Interferometric measurements of 21-cm fluctuations require large telescopes with many antennas. The sky-averaged, 'global' signal, however, may be accessible with single-dipole experiments, even during the cosmic dawn, which will not be probed with the current generation of interferometers. Moreover, the global signal provides complementary information to the fluctuations. Extracting the signal may be challenging, however: the very large foregrounds require accurate modelling, and place stringent demands on the quality of the instrumental calibration. The challenge at first appears similar to that faced by interferometric experiments, but in detail it is rather different and may well require novel approaches. A number of experiments are under way or are proposed to measure the global 21-cm signal, and it has become more urgent to address the problem of signal extraction. We present a Markov Chain Monte Carlo technique to extract the signal from data simulated for the Dark Ages Radio Explorer (DARE) which would measure the 21-cm signal at 40-120 MHz from lunar orbit. Our modelling includes the 21-cm signal, diffuse Galactic and extragalactic foregrounds, the Sun, radiation emitted by and reflected from the Moon, and a detailed parametrized description of the properties of the

instrument. We demonstrate that the signal parameters can be recovered accurately from realistic, noisy spectra with an experiment of reasonable duration, exploiting the spectral smoothness of the foregrounds and the spatial uniformity of the signal. Our method demonstrates the feasibility of DARE and validates its observational strategy, but is general and could be applied to other global 21-cm experiments. Moreover it may shed light on how to improve the design of these experiments.

304.02D – **Finding the First Metals**

Ryan J. Cooke[1], M. Pettini[1]

[1]*University of Cambridge, United Kingdom.*
10:10 AM - 10:30 AM

The first metals in our Universe were created and distributed by stars we still know very little about. Before these metals were incorporated in the second generation of stars, they were (presumably) stored within a large reservoir of gas. In this talk, I will present the results from my ongoing survey to search for this `missing-link' by targeting near-pristine damped Lyman-alpha systems (DLAs) at z~3. I report the discovery of a few systems that exhibit an abundance pattern inline with model calculations of metal-free nucleosynthesis, including notable enhancements in their C/Fe ratio; such an abundance pattern is akin to the carbon-enhanced metal-poor stars seen in the halo of our Galaxy. For the full sample of DLAs in this survey, I reinvestigate the trends of [C/O] and [O/Fe] with metallicity, and compare my findings to the recent measures of the abundances of C, O, and Fe from Galactic halo stars. I comment on the new insight this has afforded on the nature of the much-debated trends of these ratios when [Fe/H] < -2.0.

304.03D – **Radial And Azimuthal Profiles Of Mg II Absorption Around Galaxies At 0.5 < Z < 0.7**

Rongmon Bordoloi[1]

[1]*ETH Zurich, Switzerland.*
10:30 AM - 10:50 AM

We map the 2-D distribution of Mg II gas within 200 kpc (physical) of regular galaxies at redshifts 0.5 < z < 0.9 using co-added spectra from background galaxies at z > 1. We focus on the variation of Mg II rest frame equivalent width as a function of impact parameter for different subsets of foreground galaxies in terms of their rest frame colors and masses. The Mg II radial profiles can be characterized by a power law with an exponential cutoff. Blue galaxies have high average Mg II equivalent width as compared to red galaxies at close impact parameters. Blue galaxies also exhibit a correlation between Mg II equivalent width and galactic stellar mass. There is strong azimuthal dependence of the Mg II absorption around inclined disk galaxies. Absorption systems along the disk rotation axis are significantly stronger than those along the galaxy disk, indicating the presence of strongly bipolar outflows aligned along the disk rotation axis as the origin of such systems. Galaxies lying in groups have more extended radial distribution of Mg II gas as compared to that of non-group galaxies and groups as a whole have more extended radial profiles than individual galaxies. These effects can be satisfactorily modeled by a simple superposition of the absorption profiles of individual member galaxies, assuming that these are the same as those of non-group galaxies, suggesting that the group environment may not significantly enhance or diminish the Mg II absorption of individual galaxies.

304.04 – **Civ Absorbers Clustering At Z~2.4**

Shailendra Kumar Vikas[1], M. Wood-vasey[1], B. Lundgren[2], A. Myers[3], N. P. Ross[4], D. York[5], Y. AlSayyad[6]

[1]*University of Pittsburgh,* [2]*Yale University,* [3]*University of Wyoming,* [4]*Lawrence Berkeley National Laboratory,* [5]*University of Chicago,* [6]*University of Washington.*
10:50 AM - 11:00 AM

SDSS-III BOSS provides homogeneous sample of 150,000 quasar spectra during the course of survey. The spectra give important information about the intervening absorbing material as well as about the quasars themselves. We can study the clustering properties of the intervening CIV absorbers found in the quasar spectra by cross-correlating the CIV absorber sample with the well-understood sample of quasars. Measuring the linear bias for the CIV absorber systems in a large homogeneous survey allows us to constrain the origin of these CIV absorber systems. It will also provide the constraints for the feedback processes in galaxy formation theory. We study the cross correlation in the range 2.1 < z < 2.6 as the abundance of CIV absorbers and quasars overlap at these redshift. We present the results from a CIV absorber clustering study from the first 2 years of BOSS data.

304.05D – **CWI and FIREBall: Two Spectrographs Built to Observe Emission from the IGM. Instrument Design and Early Results.**

Mateusz Matuszewski[1], C. Martin[1], P. Morrissey[1], A. Moore[2], CWI Team, FIREBall Team

[1]*Caltech,* [2]*Caltech Optical Observatories.*
11:00 AM - 11:20 AM

The Cosmic Web Imager (CWI) and the Faint Intergalactic Redshifted Emission Balloon (FIREBall) are two integral field specrographs designed to investigate line emission from the intergalactic medium (predominantly Lyα, O VI, and CIV). CWI, a ground based instrument, observes in the wavelength interval 4500 to 5400 A, while FIREBall takes advantage of a narrow stratospheric balloon window around 2000 A. The performance and design of the two instruments are discussed. Results of observations of the IGM with these new tools are presented.

304.06 – **A Continuum-free Estimation of the Effective Lyman Alpha Opacity At z > 2.5**

Nao Suzuki[1], J. X. Prochaska[2], G. Worseck[2], J. Hennawi[3], J. M. O'Meara[4]

[1]*Lawrence Berkeley National Lab.,* [2]*University of California, Santa Cruz,* [3]*Max Planck Institute for Astrophysics, Germany,* [4]*St. Michael's Collage.*
11:20 AM - 11:30 AM

A fundamental measure of the IGM is its mean effective opacity to the Lyman alpha resonance line τ_{eff} via its trace number of HI atoms. A precise assessment of its value and evolution in time and place is a unique and powerful constraint on our cosmological paradigm. Quantitatively, several of the estimations at z>3 are in disagreement with offsets that significantly exceed the reported uncertainties. Furthermore, several authors using complimentary datasets have reported the detected of a `dip' in τ_{eff} at $z \approx 3.2$ that has been disputed by other work. In this work, we place new constraints on τ_{eff} using quasar spectra from the Sloan Digital Sky Survey but without estimating any intrinsic continuum.

305 – AGN, QSO, Blazars V

Oral Session – Room 17A – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

305.01 – **The Cosmic Downsizing of Fermi-detected Flat Spectrum Radio Quasars**

Marco Ajello[1], R. W. Romani[2], M. Shaw[2], C. Dermer[3], L. Costamante[2], Fermi LAT collaboration

[1]*SLAC/KIPAC,* [2]*Stanford University,* [3]*U. S. Naval Research Laboratory.*
10:00 AM - 10:10 AM

Fermi LAT, with its unprecedented sensitivity, has detected over a thousand point-like sources most of which are blazars detected over a wide range in redshift and luminosity. We will review the properties of the source populations detected by Fermi-LAT focusing in particular on the statistical properties of blazars. New results on the cosmological evolution and growth of FSRQs will be presented. Fermi data provide the first indications for the anti-hierarchical growth of FSRQs where more luminous objects form earlier in the history of the Universe while the less luminous, that form the bulk of the population, are more abundant at later epochs. The number density of FSRQs grows dramatically up to redshift ~0.5--2.0 and declines thereafter. The LF of γ-ray FSRQs follows a luminosity dependent density evolution similarly to that of AGN, but with more dramatic growth and decline rates. We find that unresolved FSRQs produce only ~10% of the isotropic gamma-ray background. Finally we find that FSRQs have an average bulk Lorentz factor of Γ = ~12 that most are seen within 5 degrees of the jet axis, and that they represent only ~0.1 % of the parent population.

305.02D – **The Co-Evolution of Galaxies and Black Holes from 0.5 < z < 2.7**

Brooke Simmons[1], C. M. Urry[1]

[1]*Yale Univ.*.
10:10 AM - 10:30 AM

Although much progress has been made in the investigation of the co-evolution of black holes and galaxies, the nature of AGN accretion triggers and AGN-host feedback remain open questions. Using a sample of X-ray selected, moderate-luminosity AGN and their host galaxies in the GOODS fields from 0.5 < z < 2.7, we assess the growth rates and histories of these black holes, and use their host galaxy morphologies and colors to test the applicability of common quasar-triggering models to lower-powered AGN. We find that moderate-luminosity AGN span a range of growth rates but are mostly in a phase of slow growth, implying that they must have been growing at higher rates in the past in order to grow to the masses we observe. Additionally, a significant fraction of the host galaxies of moderate-luminosity AGN are disk-dominated even at the highest redshifts in our sample, indicating that models requiring major mergers to trigger the growth of black holes do not describe the majority of AGN. The range of both black hole growth rates and host galaxy colors and morphologies in our sample imply that secular processes are fundamental to the growth of moderate-luminosity AGN, which collectively dominate the AGN luminosity function.

We acknowledge support from NASA through grants HST-GO-09425.13-A, HST-GO-09822.09-A, HST-AR-10689.01, and HST-AR-12638.01 from the Space Telescope

Science Institute, which is operated by the Association of Universities for Research in Astronomy under NASA contract NAS 5-26555.

305.03 – **Discovery of a Tidal Disruption Event Candidate from the 2XMM Catalog**

Dacheng Lin[1], E. R. Carrasco[2], D. Grupe[3], N. A. Webb[1], D. Barret[1], S. A. Farrell[4]
[1]IRAP, France, [2]Gemini Observatory/AURA, Chile, [3]Pennsylvania State University, [4]University of Sydney, Australia.
10:30 AM - 10:40 AM

Stars approaching a supermassive black hole (SMBH) can be tidally disrupted and subsequently accreted, providing a unique way to find and study inactive SMBHs. We report on our discovery of a new tidal disruption event candidate, 2XMMi J184725.1-631724, with unprecedented ultrasoft X-ray spectra near the flare peak. It lies toward the center of an inactive galaxy at z=0.0353. It was detected serendipitously in two XMM-Newton observations separated by 211 days, with the flux increasing by a factor of ~9. The source was not detected in X-rays by ROSAT in 1992, indicating a long-term variability factor of >64; neither by Swift in 2011, implying a flux decay factor of >12 since the last XMM-Newton observation. The XMM-Newton X-ray spectra are dominated by a strong cool thermal disk (>80%, tens of eV) with the luminosity appearing to follow the L \propto T^4 relation, often seen in the thermal state of the BH X-ray binaries. Both XMM-Newton observations show large variability on timescales of hours. This can be explained as due to fast variations in the mass accretion rate, maybe caused by the shocks during the tidal disruption of the star.

305.04 – **The Fermi Second Large Area Telescope AGN Catalog (2LAC)**

Charles D. Dermer[1], E. Cavazzuti[2], S. Cutini[2], D. Gasparrini[2], B. Lott[3]
[1]NRL, [2]ASI, Italy, [3]University of Bordeaux, France.
10:40 AM - 10:50 AM

The second LAT AGN catalog (2LAC; arXiv:1108.1420) is based on the first two years of scientific data from the Fermi Gamma ray Space Telescope. It consists of 1016 high Galactic latitude (|b|>10 degrees) sources with Test Statistic > 25 that are associated at high confidence with AGNs. The 2LAC clean sample comprises 885 sources which have unique associations and were not flagged as suspicious during the analysis, and includes 395 BL Lac objects, 310 flat spectrum radio quasars, 156 blazars of unknown type, 8 misaligned AGNs, 4 RL-NLSy1 galaxies, 10 AGNs of other types, and 2 starburst galaxies. More than 55% of the BL Lac objects do not have measured redshifts. The importance of this catalog to various topics in blazar research is summarized, including the blazar sequence, unification between beamed and misaligned AGN populations, variability and population studies, and the radio/gamma-ray and GeV/TeV connections.

305.05D – **The Radio Variability of Gamma-Ray Blazars**

Joseph Richards[1]
[1]California Institute of Technology.
10:50 AM - 11:10 AM

Since late 2007, we have regularly monitored over 1100 systematically-selected blazars at 15 GHz using the Owens Valley Radio Observatory 40m radio telescope. The number of sources in the program has grown to nearly 1600, including all the active galactic nuclei associated with Fermi Large Area Telescope (LAT) gamma-ray point source detections north of our declination limit of −20°. Here, we describe the first 42 months of this program, including the automated data reduction pipeline and MySQL database system for storing the reduced data and intermediate data products. Using the "intrinsic modulation index," a maximum-likelihood method, we estimate the variability amplitudes for 1413 sources from their radio light curves and compare the properties of physically-defined subpopulations of the sample. We find that, among our preselected sample, gamma-ray-loud blazars detected by the LAT are significantly more variable at 15 GHz, attributable to a difference in variability between the gamma-ray-loud and gamma-ray-quiet flat spectrum radio quasars. The BL Lacertae objects in the samples do not show this division in variability amplitudes. In the first two years of our program, a 3σ-significant difference between variability amplitudes for sources at redshift $z \gtrsim 1$ and for sources at $z<1$ was found. This difference is found no longer to be significant in the full 42-month data set, particularly after we apply an analysis method to account for the effect of cosmological time dilation.

This work was supported in part by NASA grants NNX08AW31G and NNG06GG1G and NSF grant AST-0808050.

305.06 – **Search for Gamma-ray Emission From X-ray Selected Radio-quiet Seyfert Galaxies with Fermi-LAT**

Masaaki Hayashida[1], L. Stawarz[2], K. Bechtol[1], G. Madejski[1], Fermi-LAT
[1]SLAC/KIPAC, Stanford, [2]JAXA/ISAS, Japan.
11:10 AM - 11:20 AM

We report on a systematic investigation of the gamma-ray properties of 120 hard X-ray-selected Seyfert galaxies classified as `radio-quiet' objects, utilizing *Fermi*-LAT data. Our sample of Seyfert galaxies is selected using the *Swift*-BAT 58-month catalog, restricting the analysis to the bright sources with average hard X-ray fluxes $F_{(14\text{-}195\ \mathrm{keV})} > 2.5\times10^{-11}$ erg cm^{-2} s^{-1} at high Galactic latitudes (|b|>10 deg). In order to remove `radio-loud' objects from the sample, we use the `hard X-ray radio loudness parameter', R_{RX}, defined as the ratio of the total 1.4 GHz radio to 14-195 keV hard X-ray energy fluxes. Among 120 X-ray bright Seyfert galaxies with $R_{\mathrm{RX}} <10^{-4}$, we did not find a statistically significant gamma-ray excess positionally coincident with any target Seyferts, with possible exceptions of ESO 323-G077 and NGC 6814. The typical value of the 95 % confidence level gamma-ray upper limit for the integrated photon flux above 100 MeV from the analyzed Seyferts is on the order of 10^{-9} ph cm^{-2} s^{-1}. Our results indicate that no prominent gamma-ray emission component related to active galactic nucleus activity is present in the spectra of Seyferts around GeV energies. The *Fermi*-LAT upper limits derived for our sample probe the ratio of gamma-ray to X-ray luminosities $L_{\mathrm{g}}/L_{\mathrm{X}} < 0.1$, and even <0.01 in some cases. The obtained results impose novel constraints on the models for high-energy radiation of `radio-quiet' Seyfert galaxies.

305.07 – **Constraining the Parameters of Kpc-scale, Relativistic, Inverse Compton X-ray Jets in AGN**

Daniel A. Schwartz[1], M. Birkinshaw[2], D. M. Worrall[2]
[1]Harvard-Smithsonian, CfA, [2]University of Bristol, United Kingdom.
11:20 AM - 11:30 AM

The X-ray emission from extended, kpc-scale jets is commonly explained as inverse Compton scattering of the cosmic microwave background (CMB) by the same population of electrons that emit the GHz radio spectrum. The radio and X-ray flux densities, and the assumption of equipartition of magnetic and relativisitic particle energy density, give three constraints to estimate four quantities of interest: the magnetic field, relativistic electron density, bulk Lorentz factor, and angle of the jet to our line of sight. Additional assumptions, such as setting the Lorentz factor equal to the Doppler factor, are generally used, e.g., to deduce the kinetic flux along the jet. We allow the angle to the line of sight to be a free parameter, and suggest a new constraint on the Lorentz factor and therefore also the Doppler factor. As the Lorentz factor increases, the photons we receive are increasingly those emitted back towards the AGN nucleus in the jet rest frame. However the cone of enhanced CMB density lies increasingly in the opposite direction. Eventually these photons no longer fall in the small cone satisfying the head-on approximation, which is built into the expressions for inverse-Compton emissivity, and the emitted spectrum would no longer have the standard form. Accordingly, the data can be used to deduce an upper limit to the Lorentz factor as a function of the angle to the line of sight.

This research was funded in part by Chandra grant GO7-8107X

306 – The Astrophysics Postdoc Job Market

Special Session – Ballroom G – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

The AAS Employment Committee will host a panel discussion on current issues related to the postdoc job market. Part of the discussion will likely focus on the recent proliferation of postdoc-type positions, including fellowships, without any corresponding growth in potentially permanent academic positions, and on the associated dramatic increase in the duration of the postdoc career stage for many astronomers. The goals of the session are: (1) to provide information to the community based on the personal experiences of successful young astronomers who have recently transitioned to tenure-track or other potentially permanent academic positions, or have gone on to non-academic career tracks; (2) to provide the perspective from an employer's point of view (e.g., those running postdoctoral fellowship programs); and (3) to promote discussion about possible changes to employment, recruitment and hiring practices impacting postdocs, and how these changes could be implemented. We encourage both junior and senior AAS members to attend and share their experiences and opinions.

307 – Evolution of Galaxies V

Oral Session – Room 19A – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

307.01 – **Measuring the M-σ Relation with Quasars from 0.2 < z < 1**

Kyle Hiner[1], G. Canalizo[1], M. Wold[2], M. Brotherton[3]

[1]University of California, Riverside, [2]Dark Cosmology Centre, Niels Bohr Institute, University of Copenhagen, Denmark, [3]University of Wyoming.

10:00 AM - 10:10 AM

It is now known that the masses of black holes, M, at the centers of galaxies correlate with host galaxy properties, including the stellar velocity dispersion, σ, of the central bulge region. The relation implies supermassive black holes and their hosts have a shared evolution, but it is only well studied in the local universe. The precise mechanism of black hole and host galaxy growth regulation is still unknown, but various models predict evolution in the relation with redshift.

We are studying the nature of the M-σ relation using two samples of quasars. 1) Our first sample consists of 29 post-starburst quasars that range in redshift from 0.2<z<0.4. Spectra of these objects simultaneously show active nucleus features and strong Balmer absorption lines, indicative of a post-starburst stellar population in the hosts. 2) Our second sample has 36 quasars ranging from 0.2<z<1 that have dust-reddened continua. This reddening extinguishes light from the active nucleus enough that host galaxy absorption features are measureable, yet not so much as to extinguish the Hα broad emission line.

We conduct spectral fitting that measures the host galaxy stellar velocity dispersion by broadening a host galaxy template with a Gaussian. We test various templates to minimize template - host galaxy mismatch. We measure the black hole masses using the virial method, which employs the broad line width and continuum luminosity as observables. We are also comparing the velocity dispersions as measured from different spectral regions in a sample of quiescent E+A galaxies.

Our preliminary results show that black holes in both post-starburst and red quasars are over-massive with respect to their hosts when compared to the M-σ relation for local AGN. Our results are generally consistent with previous work that shows an offset for high-z low-luminosity active galaxies.

307.02D – **Black Hole Masses and Scaling Relationships in Brightest Cluster Galaxies**

Nicholas J. McConnell[1], C. Ma[1], J. R. Graham[1], K. Gebhardt[2], T. R. Lauer[3], S. A. Wright[1], J. D. Murphy[2], D. O. Richstone[4]

[1]UC Berkeley, [2]UT Austin, [3]NOAO, [4]UM Ann Arbor.

10:10 AM - 10:30 AM

We present stellar dynamical measurements of black hole masses in five nearby Brightest Cluster Galaxies. Our measurements include the most massive black holes detected by direct methods and substantially increase the sample size for the high-mass ends of the black hole-bulge scaling relationships. Using our new measurements and an updated sample of black hole masses from other investigators, we find that the M_{BH}-sigma relationship steepens at both the high- and low-mass ends. The most luminous galaxies exhibit large intrinsic scatter in black hole mass, in opposition to the tight M_{BH}-L relationship predicted by models of successive hierarchical mergers. Some scatter may arise from the early growth of 10^9 -10^{10} solar-mass black holes, as indicated by the most powerful high-redshift quasars.

307.03D – **The Infrared Insights on the Nature and Evolution of Star-Forming Galaxies in the Past 11 Billion Years**

Wiphu Rujopakarn[1]

[1]University of Arizona.

10:30 AM - 10:50 AM

This thesis explores the nature of star-forming galaxies and their evolution as seen in the mid-infrared (IR) wavelengths. We first study the star formation rate density evolution by constructing the IR luminosity functions (LF) at 0 < z < 1.2. Separately, we find that star-forming galaxies at both low and high redshifts fall into a nearly linear relationship between the infrared luminosity (LIR) and infrared luminosity surface density (LIRSD) over five orders of magnitude in luminosity, which indicates that high-redshift IR luminous star-forming galaxies have similar structures to local normal star-forming galaxies and primarily differ in the 100x to 1000x higher star formation rate (SFR) surface density. We show that the LIRSD, instead of the LIR, is a good indicator of the shape of star-forming galaxies' spectral energy distributions at both low and high redshifts. This result is used to develop a new technique to estimate the LIR, which results in an indicator that predicts LIR and SFR from a single-band 24 micron observation, consistent with a full spectral energy distribution within 0.1 dex. We use this indicator to construct the IR LF of star-forming galaxies and study SFR evolution at redshift 0 < z < 3, spanning 11 billion years of the cosmic history. In addition to exploring statistical properties of large samples of galaxies, this thesis also studies individual strongly gravitationally lensed star-forming galaxies at 1 < z < 3 using near-IR and mid-IR spectroscopy with the the Large Binocular Telescope and the Spitzer Space Telescope to understand their extinction, structure, and physical conditions.

307.04 – **Star-forming Properties within the Galaxy And Mass Assembly (GAMA) Survey**

Amanda E. Bauer[1]

[1]Australian Astronomical Observatory, Australia.

10:50 AM - 11:00 AM

I introduce the Galaxy And Mass Assembly (GAMA) survey which is a spectroscopic database of ~375,000 galaxies in the local Universe over a 360 square degree region of sky. From the first data release, I show star-forming properties as a function of stellar mass over the redshift range of 0.05<z<0.35. Star formation rates (SFRs) increase as a function of stellar mass up to 3×10^{10} M⊙, then remain constant, independent of the dust correction, for the 20% of massive galaxies that are forming stars. Lower mass galaxies exhibit high specific SFRs at all redshifts up to z = 0.35. Testing simple mass-dependent parameterisations of star formation histories, we find that low-mass GAMA galaxies show higher specific SFRs than predicted by simple models derived from z ≈ 1 galaxy samples and evolved to present day. This work has been funded by the Australian Research Council.

307.05D – **Witnessing the Differential Evolution in Luminosity and Size of Disk Galaxies via Gravitational Lensing**

Kaushala Bandara[1], D. Crampton[1], C. Y. Peng[2], L. Simard[1]

[1]University of Victoria/Herzberg Institute of Astrophysics, Canada, [2]Herzberg Institute of Astrophysics, Canada.

11:00 AM - 11:20 AM

We take advantage of the magnification in size and flux of a galaxy, provided by gravitational lensing, to analyze the properties of 62 strongly lensed galaxies of the Sloan Lens ACS (SLACS) Survey. The sample of lensed galaxies span a redshift range of 0.20 <= z <= 1.20 with a median redshift of z = 0.61. We use the lens modeling code LENSFIT to derive the luminosities, sizes and Sersic indices of the lensed galaxies. The measured properties of the lensed galaxies show a primarily compact, “disk”-like population with the peaks of the size and Sersic index distributions corresponding to ~1.50 kpc and n~1 respectively. Comparison of the SLACS lensed galaxies to a non-lensing, broad-band imaging based survey shows that a lensing survey allows us to probe a galaxy population that is typically ~ 2 magnitudes fainter. Our analysis allows us to compare the <z> = 0.61 disk galaxy sample (n <= 2.5) to an unprecedented local galaxy sample of 670,131 SDSS galaxies at z ~ 0.1, which indicates that the evolution of the luminosity-size relation since z ~ 1 cannot be explained fully in terms of pure size evolution but must be caused by a combination of luminosity and size evolution. Our observations are in excellent agreement with recent numerical simulations of disk galaxies since z ~ 1 that show evidence of mass-dependent evolution where high-mass disk galaxies (stellar mass > 10^9 solar masses) evolve more in size and low-mass disk galaxies (stellar mass <= 10^9 solar masses) evolve more in luminosity. The authors gratefully acknowledge the support from the National Research Council of Canada and NSERC through Discovery grants. CYP is grateful for funding support through the Plaskett Fellowship of the Herzberg Institute of Astrophysics (National Research Council of Canada).

307.06 – **Building Massive Galaxies: Measuring Hierarchical Assembly with BOSS**

Kevin Bundy[1], D. Wake[2], C. Maraston[3], D. Thomas[3], T. Higgs[4], M. Whie[5], B. Nichol[3], A. Bolton[6], R. Skibba[7], BOSS Collaboration

[1]IPMU / U. Tokyo, Japan, [2]Yale, [3]Portsmouth, United Kingdom, [4]Portsmouth, Japan, [5]UC Berkeley, [6]U. of Utah, [7]University of Arizona.

11:20 AM - 11:30 AM

The physical processes that regulate the growth of massive galaxies remain poorly understood. Globally, it is expected that such galaxies assemble at late times, but this basic prediction of hierarchical models is largely untested because cosmic variance in the small volumes sampled by current high-z surveys swamps any potential signal. I will discuss first results from measurements of galaxy assembly with the Baryon Oscillation Spectroscopic Survey (BOSS). After carefully combining near-IR photometry from the UKIDSS Large Area Survey in order to robustly measure stellar mass, I will show how at redshifts less than 0.5, BOSS is able to track differential growth at the highest masses for the first time.

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308 – Black Holes

Oral Session – Ballroom E – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

308.01D – **Radiation-regulated Accretion onto Intermediate-Mass Black Holes**

KwangHo Park[1], M. Ricotti[1]

[1]*University of Maryland.*

10:00 AM - 10:20 AM

We study radiation-regulated gas accretion onto intermediate-mass black holes emphasizing the role of thermal and radiation pressure in limiting gas supply from large scales to the black hole. Assuming quasi-spherical symmetry, we explore how the gas accretion depends on free parameters such as radiative efficiency, black hole mass, ambient gas density/temperature, and the spectral index of the radiation. Our numerical simulations show an oscillatory behavior of the accretion rate, and thus the luminosity from the black hole. We present a model for the feedback loop and provide analytical relationships for the average/maximum accretion rate and the period of the accretion bursts. The thermal structure inside the Stromgren sphere is a key factor for the regulation process. With increasing ambient gas density and mass of black holes, eventually the accretion rate becomes limited by radiation pressure. The period of the luminosity bursts is proportional to the average size of the ionized hot bubble. But there are two distinct modes of oscillations with very different duty cycles, and that are governed by different depletion processes of the gas inside the ionized bubble.We also study how angular momentum of the gas and the motion of the black hole relative to the ambient gas affect the accretion process.

308.02 – **Tidal Disruption Rate by Spinning Supermassive Black Holes**

Michael H. Kesden[1]

[1]*NYU.*

10:20 AM - 10:30 AM

A supermassive black hole can disrupt a star when its tidal field exceeds the star's self-gravity, and can directly capture stars that cross its event horizon. For black holes with mass $M > 10^7$ solar masses, tidal disruption of main-sequence stars occurs close enough to the event horizon that a Newtonian treatment of the tidal field is no longer valid. The fraction of stars that are directly captured is also no longer negligible. We calculate generically oriented stellar orbits in the Kerr metric, and evaluate the relativistic tidal tensor at pericenter for those stars not directly captured by the black hole. We combine this relativistic analysis with previous calculations of how these orbits are populated to determine tidal-disruption rates for spinning black holes. We find, consistent with previous results, that black-hole spin increases the upper limit on the mass of a black hole capable of tidally disrupting solar-like stars to $7 * 10^8$ solar masses. We find that direct stellar capture reduces tidal-disruption rates by a factor 2/3 (1/10) at $M = 10^7$ (10^8) solar masses. The strong dependence of tidal-disruption rates on black-hole spin for $M > 10^8$ solar masses implies that future surveys like LSST that discover thousands of tidal disruption events can constrain supermassive black-hole spin demographics.

308.03D – **An X-ray Survey for Tidal Disruption Flares in Clusters of Galaxies**

W. Peter Maksym[1]

[1]*Northwestern University.*

10:30 AM - 10:50 AM

When a star is tidally disrupted by a supermassive black hole, the accreting debris produces a luminous and possibly super-Eddington flare that can last for months or even years. The rate at which these flares occur is critical to models of galaxy formation and evolution, as it is sensitive to both the black hole mass function and the stellar populations of galactic nuclei. But the extreme rarity of these events (10^{-4}-10^{-5} galaxy^{-1} year^{-1}) makes constraining the rate difficult, and requires that additional tidal flares be identified across a variety of selection methods to better characterize their properties.

Rich galaxy clusters provide excellent opportunities for surveys of rare transients with limited fields of view, such as are typical for focusing X-ray observatories. They also allow rate calculation from a uniform population of galaxies. We present results from an archival survey of rich galaxy clusters that have been observed multiple times by *Chandra* or *XMM*, and compare our derived rate to previous surveys and theoretical calculations. In addition, we present two excellent examples of tidal disruption flares, monitored over ~10 years each, and multi-wavelength analysis of their host galaxies. One of these flares has exceptional X-ray counting statistics and is associated with possible EUV evidence for super-Eddington emission. In addition, if its host galaxy is a cluster member, galaxy associated with this flare may be the smallest known galaxy to host a supermassive black hole.

This research has been supported by NASA ADP grant NNX08AJ35G.

308.04 – **Grmhd Simulations Of Misaligned Black Hole Accretion Disks**

Xiaoyue Guan[1], J. Hawley[1], J. Krolik[2], S. Noble[3]

[1]*University of Virginia,* [2]*John Hopkins,* [3]*Rochester Institute of Technology.*

10:50 AM - 11:00 AM

We present new numerical studies of a black hole accretion disk misaligned with the hole. We use 3D general relativistic magnetohydrodynamics (GRMHD) harm3d to study the dynamics of the accretion flow. For a thick torus, we confirm the results of Fragile et al., that the main disk remained tilted with respected to the hole and in the inner region the materials plunge into the hole from two streams. We find that a dominate m=2 mode forms in the inner region of the disk and extends further out as the tilt increases. We also discuss the properties of the Poynting flux in the misaligned disk system. We also use a general relativistic ray-tracing code to study the radiation properties of these disks. We found that a tilt disk can greatly changes both the imaging and spectrum properties of the inner disk. This suggest that more parameters should be considered when fitting the black hole accretion disk's spectrum and/or images.

308.05D – **Signatures of Kiloparsec-scale Black Hole Pairs**

Laura Blecha[1], A. Loeb[1], R. Narayan[1]

[1]*Harvard University.*

11:00 AM - 11:20 AM

Supermassive black hole (SMBH) pairs are expected to form in major galaxy mergers, but until recently only a few such pairs were known. Recent spectroscopic surveys have greatly increased the number of candidate dual SMBHs via identification of double-peaked narrow-line (NL) AGN. Despite this remarkable progress, the population of SMBH pairs, and particularly their relationship to double-peaked NL AGN, is not well-constrained. To this end, we model SMBH evolution in galaxy mergers using N-body/smoothed-particle-hydrodynamics simulations, focusing on NL activity in kiloparsec-scale SMBH pairs. Previous galaxy merger simulations have not considered the NL region, and photoionization models have not considered the rapidly-varying environment of merging galaxies. We make a first attempt to model the NL region in galaxy merger simulations using a semi-analytic model. We find that kiloparsec-scale double-peaked NL AGN are a fairly generic but often short-lived phase of gaseous major mergers, lasting from less than a Myr to tens of Myr. The double-peaked features originate from a combination of SMBH motion and gas kinematics; only a minority arise from comparable-luminosity NL regions orbiting on kpc scales. NL AGN are most active in nearly equal-mass, gas-rich mergers, though we note that dust obscuration should be more important in these cases. Furthermore, NL AGN activity typically peaks during the final stage of galaxy merging, which coincides with the kpc-scale phase as well as the phase following the BH merger. We discuss the implications of our findings for efforts to confirm AGN pair candidates via follow-up observations.

308.06 – **Comptonization Model for Phase Lags in Black Hole Candidates in Low-Hard Spectral State**

Nikolai Shaposhnikov[1]

[1]*Goddard Space Flight Center.*

11:20 AM - 11:30 AM

One aspect where RXTE has particularly excelled is observations of Galactic black holes candidates, providing high cadence and quality data on these dynamic, unpredictable and enigmatic systems. One of the puzzling aspects of these observations is the behavior of the variability time delays between soft and hard energy bands, inferred from the difference between corresponding Fourier phases. These time and phase delays are functions of the Fourier frequency when these systems are in a non-thermal, highly variable, low-hard state (LHS). We develop a physical model based on the Fourier formalism and Comptonization scenario, which readily explains the complex behavior of phase delays in the LHS. A simple analytical model successfully reproduces the phase delay dependence on frequency and leads to the proper determination of the photon delay times in a Comptonizing corona. The time delay shows a logarithmic dependence on energy in excellent agreement with the Comptonization model. Combined with the RXTE spectral data, our timing analysis provides a complete characterization of the corona in terms of electron density, temperature and size. Our results strongly point to Comptonization as a primary mechanism for the formation of temporal and spectral properties of BHC in low-hard state. It also opens an exciting prospect for mass measurements of the central BH.

308.07 – **State Transitions and MHD Winds In GRO J1655-40**

Joseph Neilsen[1], J. Homan[1]

[1]*MIT Kavli Institute.*

11:30 AM - 11:40 AM

During its 2005 outburst, GRO J1655-40 was observed at high spectral resolution with the *Chandra* HETGS, revealing a spectrum rich with blueshifted absorption lines of elements ranging from oxygen to nickel, including exotic metals like titanium and scandium (Miller et al. 2006, 2008). To date, this spectrum remains the only conclusive observational evidence for magnetically-driven winds in an X-ray binary. Using a second HETGS observation of this microquasar from the very same outburst, we present new results on the origin and structure of the accretion disk wind throughout the outburst. We show how the wind evolves from higher ionization to lower ionization over a period of weeks, as the black hole moves from the jet-launching hard state into a softer state. We address this photoionization evolution in the context of changes in the broadband X-ray spectrum and the role of winds in outburst. We discuss the implications for models of magnetically-driven outflows from black hole binaries.

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309 – ALMA Cycle 0 Early Science and Capabilities for Cycle 1 Science

Special Session – Room 17B – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

The Atacama Large Millimeter/submillimeter Array (ALMA) will soon provide an unprecedented combination of sensitivity, image fidelity, and resolution at millimeter and submillimeter wavelengths that will open new scientific frontiers. ALMA will probe the Universe at wavelengths from 0.3 to 9.6 mm (950 - 31 GHz), a key part of the electromagnetic spectrum, for example, for observing the first stars and galaxies, directly imaging planetary formation, and studying the energy output from supermassive black holes in starburst galaxies.

This Special Session will describe: (a) ALMA Early Science conducted during the initial Cycle 0 observing period; (b) the additional capabilities that will be available to community for the Cycle 1 ALMA Early Science opportunity; and (c) the extensive support provided to observers in the US and Canada through the North American ALMA Science Center (NAASC).

The ALMA Early Science (Cycle 0) Call for Proposals was released on 30 March 2011, and observing proposals are due 30 June 2011. Early Science data acquisition for successful Cycle 0 proposals will span nine months and is expected to begin on 30 September 2011 or shortly thereafter. It is anticipated that 500-700 hours of ALMA observing time will be allocated to Cycle 0 research projects that will span many fields of astrophysics.

The key capabilities available for Cycle 1 ALMA Early Science will be described, including the array configurations, receivers, and correlator modes. This Session will also discuss the latest versions of the Observing Tool (OT) for proposal preparation and submission, the Common Astronomy Software Applications (CASA) package for science data reduction, the "observing simulator" task, and Splatalogue, an on-line spectral line database. The expected deadline for ALMA Cycle 1 proposals is March/April 2012.

309.01 – **The Current Status of ALMA**

Alison Peck[1]

[1]*ALMA, Chile.*

10:00 AM - 10:15 AM

ALMA Commissioning and Science Verification started in January 2010 with the achievement of phase closure at the telescope site at 5000m in northern Chile. This was soon followed by Science Verification, which involves making "end to end" science observations with at least 8 antennas. Starting in January 2011, we have been making very rapid progress integrating antennas and testing new observing modes, and along the way we have released a few datasets of Science Verification observations. At present, there are ~30 scientists from all over the world working at the Joint ALMA Observatory in Santiago, all of whom are assisting with Commissioning and Early Science activities as well as carrying out their own research programs. In this talk, I will summarize the current status of the array and the preparations for the next phase of Early Science.

309.02 – **Circumstellar Disks and Planet Formation with ALMA: Early Data**

A. Meredith Hughes[1]

[1]*UC Berkeley.*

10:18 AM - 10:33 AM

As ALMA enters its early science phase, it is poised to address central questions about circumstellar disks and the properties of the planets they produce. The unprecedented spatial resolution and sensitivity available during Cycles 0 and 1 will allow users to characterize the structure, dynamics, and chemistry of circumstellar disks across their evolutionary spectrum. ALMA provides unique insight into the earliest stages of dust coagulation, the enigmatic dispersal process of primordial gas and dust, and the interaction between disks and the young planets they produce. I will discuss how ALMA observations in early science and beyond will address open questions in the field, highlighting initial results and showcasing data hot off the telescope.

309.03 – **Star Formation Studies with ALMA in Cycle 0 and Cycle 1**

Yancy L. Shirley[1]

[1]*Univ. of Arizona.*

10:36 AM - 10:51 AM

In the next few years, ALMA observations of dense cores will revolutionize our understanding of star formation. In this talk, I shall highlight the capabilities of ALMA in Cycle 0 and Cycle 1 for studies of star formation. Focusing on nearby star-forming cores where we have the highest spatial resolution, I shall discuss how ALMA will probe the magneto-hydrodynamics of infall/collapse and will constrain the structure of the inner envelope and disk. I shall also discuss important issues (i.e. appropriate dust opacities, etc.) that must be considered in radiative transfer modeling of ALMA observations.

309.04 – **ALMA's First Insights into the Submillimeter/millimeter Extragalactic Universe**

Carol J. Lonsdale[1]

[1]*NRAO.*

10:54 AM - 11:09 AM

As Early Science observations begin, ALMA is poised to investigate the dusty and molecular extragalactic Universe, from our nearest neighbors to the first galaxies. I will present prospects and early results for extragalactic studies from ALMA's first observing campaigns. Even its current Early Science mode, ALMA will achieve unprecedented sensitivity, frequency range and angular resolution. This will allow it to image the detailed kinematics of molecular flows in nearby AGN cores, resolve individual star-forming structures in other galaxies, and constrain the dynamics of the interstellar medium in cataclysmic mergers of the sort that trigger starbursts and quasars shortly after the epoch of re-ionization. I will demonstrate these fantastic capabilities by showing highlights from the first Early Science and Science Verification observations, including imaging of the nearby major mergers NGC 3256 and the Antennae.

309.05 – **ALMA Support from the North American ALMA Science Center (NAASC)**

Al Wootten[1]

[1]*NRAO.*

11:12 AM - 11:27 AM

The North American ALMA Science Center (NAASC) at the National Radio Astronomy Observatory (NRAO) in Charlottesville will provide user support for ALMA in North America. Early Science Cycle 0, featuring a limited yet scientifically powerful number of antennas and capabilities, began a few months ago. This talk focuses on support available to users through the NAASC from proposal submission through reduction and publication. Capabilities expected to be available at the next call for proposals (ALMA Cycle 1) observations, scheduled to commence in late North American summer, will also be discussed.

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310 – Gamma Ray Bursts

Oral Session – Room 18C – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

310.01 – **A New Limit on Lorentz Invariance and Chromatic Dispersion Across the Universe from GRB 090510A**

Robert J. Nemiroff[1], R. Connolly[1], J. Holmes[1]

[1]*Michigan Technological Univ.*.
10:00 AM - 10:10 AM

A high-energy, fast-variability time scale for Fermi-detected gamma-ray burst GRB 090510A is found that creates a new strictest upper limit on the energy dependence of the speed and dispersion of light across the universe. In particular, evidence is presented for variability at or below $\Delta t = 0.00136$ for super-GeV photons, a factor of 10 more limiting than any time scale previously claimed for a GRB at GeV energies, including a previous limit reported by Abdo et al (2008). This variability derives from the duration of three separate closely-arriving photon groups prominent only in photon data above 1 GeV. One pulse pair has an energy difference of $\Delta E >/\sim 23.5$ GeV. Coupled with a redshift of $z >/\sim 0.897$, the resulting limits on the differential speed of light and Lorentz invariance were found for a concordance cosmology. It was found that $\Delta c / c < 6.09 \times 10^{-21}$, a limit consistent with, but slightly stronger than, a previous limit found for a GRB by Schaefer in 1999. Given a generic dispersion relation across the universe where the time delay is proportional to the photon energy to the first power, the variability translates into a dispersion strength of $k_1 < 1.38 \times 10^{-5}$ sec Gpc^{-1} GeV^{-1}. This limit results in an upper bound on dispersive effects created, for example, by dark energy, dark matter, or the spacetime foam of quantum gravity. This dispersion constraint also results in the most stringent lower limit yet claimed for the onset energy scale of quantum gravity: $M_{QG} c^2 > 7.43 \times 10^{21}$ GeV.

310.02 – **Mechanism for Gamma-Ray Bursts and Black Hole Universe Model**

Tianxi Zhang[1]

[1]*Alabama A&M University.*
10:10 AM - 10:20 AM

Gamma-ray bursts are the most energetic events occurred in the universe. They are usually categorized into long and short gamma-ray bursts according to their durations of being greater than two seconds or not. It is generally believed that the long gamma-ray bursts are produced by the collapse of massive stars to form compact objects such as neutron stars and stellar black holes, while the short gamma-ray bursts are produced by the merger of binary neutron stars. However, the mechanism or mean by which gamma-ray bursts convert their energies into high-frequency radiations remains poorly understood. In this study, a new mechanism for gamma-ray bursts is proposed, in accord with the black hole universe model recently developed by the author from considering a black hole as a spacetime and slightly modifying the big bang theory. According to the black hole universe model, both the merger of stellar black holes to form a larger one and the collapse of a massive star into a stellar black hole would release a huge amount of high-frequency radiation such as gamma-rays. The results obtained for the energy emission by both the long and short gamma-ray bursts can be consistent with measurements. This work is supported by NASA EPSCoR and AAMU title III programs.

310.03D – **Testing and Improving the Luminosity Relations for Gamma-Ray Bursts**

Andrew C. Collazzi[1]

[1]*Louisiana State University.*
10:20 AM - 10:40 AM

Gamma Ray Bursts (GRBs) have several luminosity relations where a measurable property of a burst light curve or spectrum is correlated with the burst luminosity. These luminosity relations are calibrated for the fraction of bursts with spectroscopic redshifts and hence the known luminosities. GRBs have thus become known as a type of "standard candle"; where standard candle is meant in the usual sense that luminosities can be derived from measurable properties of the bursts. GRBs can therefore be used for the same cosmology applications as Type Ia supernovae, including the construction of the Hubble Diagram and measuring massive star formation rate. The greatest disadvantage of using GRBs as standard candles is that their accuracy is lower than desired. With the recent advent of GRBs as a new standard candle, every effort must be made to test and improve the distance measures.

Here, methods are employed to do just that. First, generalized forms of two tests are performed on the luminosity relations. All the luminosity relations pass one of these tests, and all but two pass the other. Even with this failure, redundancies in using multiple luminosity relations allows all the luminosity relations to retain value. Next, the "Firmani relation" is shown to have poorer accuracy than first advertised. It is also shown to be derivable from two other luminosity relations. For these reasons, the Firmani relation is useless for cosmology. The Amati relation is then revisited and shown to be an artifact of a combination of selection effects. Therefore, the Amati relation is also not good for cosmology. Fourthly, the systematic errors involved in measuring a luminosity indicator (E_{peak}) are measured. The result is an irreducible systematic error of 28%. Finally, the work concludes with a discussion about the impact of the work and the future of GRB luminosity relations.

310.04 – **Metallicity in the GRB100316D/SN 2010bh Host Complex**

Emily M. Levesque[1], E. Berger[2], A. M. Soderberg[2], R. Chornock[2]

[1]*University Of Colorado Boulder,* [2]*Harvard University.*
10:40 AM - 10:50 AM

The recent long-duration GRB 100316D, associated with supernova SN 2010bh and detected by Swift, is one of the nearest GRB-SNe ever observed ($z = 0.059$). This provides us with a unique opportunity to study the explosion environment on ~kpc scale in relation to the host galaxy complex. Here we present spatially-resolved spectrophotometry of the host galaxy, focusing on both the explosion site and the brightest star-forming regions. Using these data, we extract the spatial profiles of the relevant emission features (H-alpha, H-beta, [OIII] 5007A, and [NII] 6584A), and use these profiles to examine variations in metallicity and star formation rate as a function of position in the host galaxy. We conclude that GRB 100316D/SN2010bh occurred in a low-metallicity host galaxy, and that the GRB-SN explosion site corresponds to the region with the lowest metallicity and highest star formation rate sampled by our observations. Combining our work with other recent spatially-resolved studies of nearby GRB host galaxies, these results have compelling implications for larger-scale studies of LGRB host environments at higher redshifts. This research was supported in part by NASA through an Einstein Postdoctoral Fellowship.

310.05D – **On the Metal Aversion of LGRBs**

John Graham[1], A. Fruchter[2], E. Levesque[3], K. L.[3], B. J.[4], A. Levan[5], N. Tanvir[6], S. Patel[7], G. Aldering[8], S. Perlmutter[8], K. Misra[2], K. Huang[1], D. Reichart[9], M. Nysewander[2]

[1]*Space Telescope Science Inst. & Johns Hopkins Univ.,* [2]*Space Telescope Science Inst.,* [3]*Institute of Astronomy, University of Hawaii,* [4]*Leiden Observatory, Netherlands,* [5]*University of Warwick, United Kingdom,* [6]*University of Leicester, United Kingdom,* [7]*National Space Science & Technology Center,* [8]*Lawrence Berkeley National Lab,* [9]*University of North Carolina at Chapel Hill.*
10:50 AM - 11:10 AM

We discuss recent observations of several high metallicity LGRBs hosts. We then compare the entire population of LGRB hosts with measured metallicities to the hosts of Type II and broad-lined Type Ic SNe as well as the star-forming SDSS galaxy population using several methods of analysis. We argue that even though a few LGRBs do lie in fairly metal rich hosts, the general population of LGRB hosts is surprisingly metal poor, and that metallicity must be an important factor in the formation of LGRBs. Finally we conclude with a discussion of the potential importance and practicality of obtaining spatiality resolved metallicity measurement of LGRB host galaxies.

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311 – Spiral Galaxies: Evolution of Halos, Bars, and Discs

Oral Session – Room 18B – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

311.01 – **Baryons and the Dark Matter Halos of Low Surface Brightness Galaxies**

Rachel Kuzio de Naray[1], K. Spekkens[1]

[1]*Royal Military College of Canada, Canada.*
10:00 AM - 10:10 AM

The addition of baryonic physics to simulations of galaxy formation has been instrumental in producing realistic massive and Milky Way-analog disk galaxies that are bulgeless or only moderately bulged. Additionally, in recent simulations of dwarf galaxies, processes that remove or redistribute baryons during galaxy formation have been shown to alter the inner shape (triaxial to more spherical) and density structure (cuspy to more core-like) of dark matter halos. We compile observational properties of dark matter-dominated low surface brightness (LSB) galaxies to evaluate the plausibility that a previously higher baryonic mass content and feedback from star formation can modify the dark matter halos of these galaxies. We also compare the properties of bulgeless disk galaxies formed in recent simulations to the LSB galaxy sample. We find that observational constraints on LSB galaxy star formation histories, structure, and kinematics make it difficult for baryonic physics to sphericalize and decrease the central density of the dark matter halos of LSB galaxies.

311.02 – **Stellar Halos Of Galaxies Beyond The Local Group**

Jeremy Bailin[1], E. F. Bell[1], S. N. Chappell[1], D. Radburn-Smith[2], R. de Jong[3]

[1]*University of Michigan,* [2]*University of Washington,* [3]*Leibniz-Institut für Astrophysik Potsdam (AIP), Germany.*
10:10 AM - 10:20 AM

Until recently, quantitative measurements of the global properties of the stellar halos of

galaxies have been confined to the Local Group: HST can resolve stellar halo stars but only over a small field of view, while it has been difficult to resolve these stars in ground-based imaging.

I will present new Magellan/IMACS wide-field imaging around 5 galaxies located at 2-4 Mpc, where we detect red giant branch stars in the halos of these galaxies. I will discuss how we use these data in conjunction with GHOSTS HST/ACS imaging of small overlapping fields to measure the luminosities, masses and structure of the halos of these galaxies out to 30 kpc.

311.03 – **Galaxy Zoo: The Environmental Dependence of Bars and Bulges in Disc Galaxies**

Ramin A. Skibba[1], K. L. Masters[2], R. C. Nichol[2], I. Zehavi[3], B. Hoyle[4], E. M. Edmondson[2], Galaxy Zoo

[1]*University of Arizona,* [2]*University of Portsmouth, United Kingdom,* [3]*Case Western Reserve University,* [4]*University of Barcelona, Spain.*
10:20 AM - 10:30 AM

We present an analysis of the environmental dependence of bars and bulges in disc galaxies, using a volume-limited catalogue of 16397 galaxies at $z<0.06$ from the Sloan Digital Sky Survey that have visual morphologies from the Galaxy Zoo 2 project. We confirm that the likelihood of having a bar or bulge in disc galaxies increases when the galaxies have redder optical colours and larger stellar masses, and observe a transition in the bar and bulge likelihoods, such that massive disc galaxies with high stellar mass surface densities, old stellar populations, and low star formation rates and gas masses are more likely to host bulges and bars. However, we find that bar and bulge likelihood are not monotonically correlated with each other. In addition, while most bulge-dominated disc galaxies are massive and on the 'red sequence' of the colour-magnitude diagram, a wider variety of optical colours is seen in galaxies that host bars.

We use two-point galaxy clustering methods to demonstrate statistically significant environmental correlations of both barred and bulged galaxies, from projected separations of 150 kpc/h to 3 Mpc/h. We demonstrate that a large fraction (30-90%) of the bar-environment correlation is explained by more massive dark matter haloes hosting redder disc galaxies which in turn are more likely to have bars. This is shown with two independent tests: (1) by shuffling the bar likelihood at a given colour; and (2) using an SDSS-like mock galaxy catalogue in which bar likelihoods are assigned based on the model galaxy colour. In contrast, the environmental dependence of stellar mass explains less of the bar-environment correlation. Finally, by analyzing the clustering measurements with halo occupation models, we argue that unbarred galaxies are dominated by central galaxies in low-mass haloes, while the satellite disc galaxies in more massive haloes are more likely to form bars.

311.04D – **New Observational Constraints on the Formation and Evolution of Galactic Disks though Gas Accretion and Bar-Driven Inflows**

Wang Jing[1]

[1]*Max Planck Institute for Astrophysics, Germany.*
10:30 AM - 10:50 AM

We analyze a sample of massive HI-rich galaxies in the local universe, which have HI mass measurements available from the Arecibo telescope . We find that galaxies with larger HI fractions have bluer, more actively a star-forming outer disks. Our results strongly support an ``inside-out'' picture of disk galaxy formation. The lack of any intrinsic connection between HI fraction and galaxy asymmetry suggests that gas is accreted smoothly onto the outer disk. We have also developed algorithms to identify and measure the ellipticity and sizes of bars and applied this to a sample of 3890 face-on massive disk galaxies in the Sloan Digital Sky Survey. We show that the fraction of galaxies with strong bars is highest for high mass galaxies with low surface densities and concentrations. Among these galaxies, the bar fraction peaks in galaxies with both higher and lower-than-average rates of central star formation This suggests that bars may play a role in inducing gas inflows that build central bulge components in galaxies. We speculate that the formation of the bulge may lead to the eventual quenching of star formation in galaxies. We also find that the size of the bar relative to the disk depends most strongly on the mean stellar age of the galaxy, supporting scenarios in which the growth of bars is regulated by gas accretion.

311.05D – **Radial Variation in Vertical Structure of Edge-On Galaxies**

Kijeong Yim[1], T. Wong[1]

[1]*University of Illinois at Urbana-Champaign.*
10:50 AM - 11:10 AM

We study vertical structure of a sample of edge-on galaxies (NGC 891, 4013, 4157, 4565, and 5907) using BIMA/CARMA 12CO (J=1->0), VLA/EVLA HI, and Spitzer 3.6 um data. First, we obtain inclinations for less edge-on galaxies (NGC 4157, 4565, 5907) to enable determination of the CO and HI disk thickness as a function of radius. We derive the thicknesses of CO and HI disks, taking into account projection effects for galaxies that deviate significantly from being edge-on. We use a sech^2 function to obtain the stellar scale height with radius for all galaxies. Using our measurements of the disk thickness and the radial distribution, we estimate volume densities and pressures as a function of radius and height in order to test the importance of pressure in controlling the molecular-to-atomic gas ratio. In addition, the gas volume density provides a new approach to probing the star formation law, one that is more physically relevant to the star formation rate. We measure the vertical velocity dispersion as a function of radius for both gas and stars by solving the Poisson equation. We show that the disk thicknesses increase with radius and the velocity dispersions decrease with radius, which are contrary to the assumed constant values used in many studies. We investigate how the interstellar pressure and the gravitational instability parameter differ from values derived assuming constant velocity dispersions and scale heights.

311.06 – **SWELLS: A Large Sample Of Spiral Lens Galaxies**

Tommaso Treu[1], SWELLS team

[1]*University of California.*
11:10 AM - 11:20 AM

I present first results from SWELLS, the Sloan Lenses WFC Edge-on Late-type Lens Survey. Lenses are first identified spectroscopically and visually from SDSS database and then confirmed via Hubble Space Telescope imaging. The ongoing survey comprises ~20 spiral galaxies acting as strong lenses to date. Extensive follow-up is ongoing with the Keck Telescope to obtain spatially resolved kinematics, K-band AO images, and perform a joint lensing and dynamical analysis to reconstruct the dark and luminous mass distribution and properties of the stellar orbits. I discuss the results in terms of their implication for understanding the formation and evolution of spiral galaxies and the absolute normalization of their stellar initial mass function.

I acknowledge support from NASA through HST grants GO-12292 and GO-11978 and from the Packard Foundation.

311.07D – **Investigating Stellar Feedback Models in Hydrodynamics Simulations**

Cameron B. Hummels[1]

[1]*Columbia University.*
11:20 AM - 11:30 AM

Employing the hydrodynamics code Enzo, we perform adaptive mesh refinement (AMR) simulations to create and evolve a Milky-Way-mass disk galaxy in a larger cosmological environment. Using one set of initial conditions, we produce a series of runs where we systematically modify the star formation and stellar feedback models to investigate their effects on the dynamics of this galaxy by $z = 0$. Studying these results, we search for ways to avoid the spurious buildup of material in the core of the galaxy (i.e. the angular momentum problem) and for ways of producing realistic galactic outflows. The modifications made include: (i) spatial resolution, ranging from 1700 to 212 pc; (ii) an additional pressure component to ensure that the Jeans length is always resolved; (iii) low star formation efficiency, going down to 0.1%; (iv) fixed physical resolution as opposed to comoving resolution; (v) a supernova feedback model which injects thermal energy to the local cell; and (vi) a subgrid feedback model which suppresses cooling in the immediate vicinity of a star formation event. From these options, we find that only artificial cooling suppression has any impact on reducing the incidence of the angular momentum problem and producing a less-peaked rotation curve; however, even those runs which do not achieve flat rotation curves can produce outflows of metal-rich gas into the halo of this galactic system.

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312 – Cosmology I

Oral Session – Ballroom D – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

312.01 – **Life On The Edge: A Measurement Of The Cosmic UV Background At Z~0**

Juan M. Uson[1], J. J. Adams[2], G. J. Hill[3], P. J. MacQueen[3]

[1]*Observatoire De Paris - LERMA, France,* [2]*Carnegie Observatories,* [3]*McDonald Observatory, University of Texas at Austin.*
10:00 AM - 10:10 AM

We have used the VIRUS-P integral-field spectrometer on the University of Texas McDonald Observatory 2.7m telescope to observe the edge of the superthin spiral galaxy UGC7321. We detect faint Hα emission as expected from the exposure of the peripheral neutral Hydrogen gas traced by its 21cm radio emission to the metagalactic UV background. Observations of the intensity of the UV background and its redshift evolution are important to the theory and simulations of the evolution of large scale structure in the Universe as the UV background controls the cooling and collapse of small halos and is itself determined by the global histories of quasar and star formation. We have used dithered expositions with three pointings that fill in the gaps in the VIRUS-P detector for essentially full spatial coverage over a field of view of 1.6′ x 1.6′ and a spectral resolution of R = 3860 from 6040 Å to 6740 Å that allows us to resolve bright OH sky lines and geocoronal Hα from our target wavelength of 6574 Å. The Hα

layer appears rather thin, with a peak surface brightness of $\Sigma = 1.4 \times 10^{-19}$ erg s^{-1} cm^{-2} $arcsec^{-2}$ $Å^{-1}$ for spectra smoothed with a 15″ spatial kernel. This leads to a measurement of the cosmic UV background induced HI photoionization rate $\Gamma = 3.4 \times 10^{-14}$ s^{-1} (~5σ, preliminary absolute calibration). Contrary to past observational attempts, our measurements covered a large, two-dimensional on-sky area. We reach flux limits that are ~50 times fainter than the sky background with significant smoothing over spatial elements and applying a sky background model that accounts for variations in the spectral resolution of our instrument. At this writing, we are continuing with the analysis of the data. Final results will be announced at the meeting.

312.02D – **Fluctuations In The Cosmic Infrared Background Using the Cosmic Infrared Background ExpeRiment (CIBER).**

Joseph Smidt[1], T. Arai[2], J. Battle[3], J. J. Bock[4], A. Cooray[1], C. Frazer[1], V. Hristov[4], B. Keating[5], M. Kim[6], D. Lee[7], P. Mason[4], T. Matsumoto[6], K. Mitchell-Wynne[1], U. Nam[7], T. Renbarger[5], A. Smith[8], I. Sullivan[9], K. Tsumura[10], T. Wada[10], M. Zemcov[4]
[1]UC Irvine, [2]University of Tokyo, Japan, [3]JPL, [4]Caltech, [5]UC San Diego, [6]Seoul National University, Korea, Republic of, [7]Korea Astronomy and Space Science Institute, Korea, Republic of, [8]Brigham Young University, [9]University of Washington, [10]Japan Aerospace Exploration Agency, Japan.
10:10 AM - 10:30 AM

The clustering properties of faint unresolved sources may be probed by examining the anisotropies they create in the Cosmic Infrared Background (CIB). Using information from fluctuations in the CIB at different wavelengths allows us to disentangle how clustering relates to redshift. In this talk, preliminary measurements of clustering using data from the Cosmic Infrared Background ExpeRiment (CIBER), a rocket-borne experiment designed to detect the signatures of unresolved infrared galaxies during reionization, will be discussed. The CIBER payload contains four instruments including two wide field imagers designed to measure fluctuations in the near IR cosmic infrared background (CIB) at 1.0 and 1.6 microns on scales between 0.2 and 100 arcmin in both bands, where the clustering of high-redshift sources is expected to peak. CIBER observations may be combined with Akari/NEP and Spitzer/NDWFS near-infrared surveys to check systematic errors and to fully characterize the electromagnetic spectrum of CIB fluctuations.

312.03 – **New Results from Using Inhomogeneous Cosmological Models in an Era of Precision Cosmology Observations**

Mustapha B. Ishak[1], A. Nwankwo[1], A. Peel[1]
[1]Univ. Of Texas at Dallas.
10:30 AM - 10:40 AM

We use general Szekeres inhomogeneous cosmological models (i.e. not spherically symmetric and not axially symmetric) in order to derive observable functions such as cosmological distances and redshift. We also derive growth rate equations for some sub-cases. We will discuss some of our recent results using these new frameworks and show how they can offer new interpretations of the cosmological data. The results can have interesting implications for dark matter, dark energy, and large scale structure formation. This work is supported by a grant from NASA.

312.04D – **Analytical Study on the Cosmological Large-scale Structure in an Accelerating Universe**

Xin Wang[1]
[1]Johns Hopkins University.
10:40 AM - 11:00 AM

Motivated by the roughly log-normal probability density distribution function (PDF) of the small scale density field, we develop cosmological perturbation theory for the power spectrum of a logarithmically transformed density field with the formalism which is developed in the context of the cosmological renormalized perturbation theory. Compared with the standard perturbation theory, our approach help to regulate the convergence behavior of the perturbation series, and of the Taylor series expansion we use for the logarithmic mapping. The perturbation calculation achieved good agreement with simulation results. Then we consider the topology of the iso-density contour of the density field, especially the genus. The genus is relatively insensitive to nonlinear gravitational evolution, clustering bias and redshift distortion, and is approximately conserved over time as structures grow in Einstein's general relativity, hence it can be used as a robust standard ruler for cosmological measurements. However, in modified gravity models where structures grow with different rates on different scales, the genus should change over time, and therefore it can be used to test the gravity models on large scales. We studied the case of the f(R) theory, DGP brane-world theory as well as phenomenological models. We also forecast how the modified gravity models can be constrained with optical/IR or 21cm surveys in the near future.

312.05 – **Cosmological Information in Weak Lensing Peaks and Impact of Baryons**

Xiuyuan Yang[1], Z. Haiman[2], M. May[3]
[1]Columbia University; Brookhaven National Laboratory, [2]Columbia University, [3]Brookhaven National Laboratory.
11:00 AM - 11:10 AM

Recent studies have shown that the number of peaks in weak lensing maps, obtained from large forthcoming surveys such as LSST, will contain significant cosmological information. We follow up on this finding, and use a suite of WL convergence maps, obtained from ray-tracing N-body simulations and halo finder to study (i) the physical origin of the WL peaks, and (ii) to contrast the statistics of WL peaks and their dependence on the background cosmology with those expected in a Gaussian random field. In particular, we find the number of peaks as a function of their height complements more traditional statistics, such as the WL power spectrum, and will tighten constraints on cosmological parameters.

These conclusions were derived from N-body simulations that neglect changes in the lensing potential due to the presence of baryons. To answer the question how baryons impact these results, we model the effect of baryons, by modifying the dark matter halo profiles in ray-tracing N-body simulations by hand, mimicking the cooling and condensation of baryons and star-formation in halos. This allows us to study (i) the impact of baryons on the WL peak counts, and (ii) to access how much the inferred cosmological parameters would be biased if the data were fit ignoring the baryons.

312.06 – **Constraining Population-III Stars Using High Redshift Gamma-Ray Sources**

Rudy Gilmore[1]
[1]SISSA/ISAS, Italy.
11:10 AM - 11:20 AM

The Fermi satellite has detected GeV emission from a number of gamma-ray bursts and active galactic nuclei at high redshift, z = 1.5. I will discuss the constraints that the detections of gamma rays from several of these sources place on the contribution of population-III stars to the extragalactic background light. Emission from these primordial stars, particularly redshifted Lyman-alpha emission, can interact with gamma rays to produce electron-positron pairs and create an optical depth to the propagation of gamma-ray emission, and the detection of emission at >10 GeV can therefore constrain the production of this background. I consider two possible initial mass functions for early stars, and use derived SEDs for each to put upper limits on the star-formation rate density of massive early stars from redshifts 6 to 10. Current data can limit star-formation in the late stages of reionization to be less than 0.5 $M_\odot$ yr^{-1} Mpc^{-3}, and future data over the lifetime of Fermi can be expected to strengthen these limits. These results also show that the contribution to the local background flux from population-III stars must be considerably less than that from resolved galaxies, at wavelengths below 1.5 microns.

312.07 – **Why We're Exponents Of Quantifying Large-scale Structure With The Log-density**

Mark C. Neyrinck[1], B. Falck[1], I. Szapudi[2], A. Szalay[1]
[1]Johns Hopkins Univ., [2]IfA, University of Hawaii.
11:20 AM - 11:30 AM

I will discuss some reasons why the log-density should be used instead of the conventional overdensity to quantify the large-scale structure of the Universe. To some approximation, structure formation is an exponential mapping from the initial Gaussian field. Also practically, cosmological-parameter constraints from the matter log-density power spectrum than the conventional matter power spectrum.

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313 – Solar-mass Stars and Smaller

Oral Session – Room 19B – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

313.01 – **The Stellar Activity - Rotation relationship**

Nicholas James Wright[1], J. J. Drake[1], E. E. Mamajek[1], G. W. Henry[1]
[1]Harvard-Smithsonian Center for Astrophysics.
10:00 AM - 10:10 AM

We present a detailed analysis of the stellar activity - rotation relationship based on a new sample of 824 solar and late-type stars with X-ray luminosities and rotation periods. This is used to study the relationship between these parameters for both fast and slow rotators. From an unbiased subset of this sample the power law slope of the unsaturated regime is fit as B=-2.70+/-0.13. This is inconsistent with the canonical B=-2 slope to a confidence of 5 sigma, and argues for an additional term in the dynamo number equation. From a simple scaling analysis this implies that the differential rotation of solar-type stars gradually declines as they spin down. Super-saturation is observed for

the fastest rotators in our sample and its parametric dependencies are explored. Significant correlations are found with both the corotation radius and the excess polar updraft, the latter theory providing a stronger dependence and being supported by other observations. We estimate mass-dependent empirical thresholds for saturation and super-saturation and map out three regimes of coronal emission as a function of stellar mass and rotation period. Late F-type stars are shown never to pass through the saturated regime, passing straight from super-saturated to unsaturated X-ray emission. The theoretical threshold for coronal stripping is shown to be significantly different from the empirical saturation threshold, suggesting it is not responsible. Instead we suggest that a different dynamo configuration is at work in stars with saturated coronal emission. This is supported by a correlation between the empirical saturation threshold and the time when stars transition between convective and interface sequences in rotational spin-down models.

313.02 – **A Rotation-Activity Relation for Late-type M Dwarfs**

Andrew A. West[1], K. L. Weisenburger[1], J. Irwin[2], B. Wright[1], D. Charbonneau[2], M. Agueros[3], Z. K. Berta[2], J. J. Bochanski[4], K. R. Covey[5], N. M. Law[6]

[1]*Boston University,* [2]*Harvard-Smithsonian Center for Astrophysics,* [3]*Columbia University,* [4]*Penn State University,* [5]*Lowell Observatory,* [6]*University of Toronto.*
10:10 AM - 10:20 AM

A large fraction of field mid-to-late M dwarfs are found to be magnetically active, yet the exact mechanisms governing this activity are not well-understood. Simulations and observations indicate that rotation may play a role in magnetic field generation for these fully-convective stars, but the interpretation has been hampered by a lack of measured rotation rates for slowly-rotating stars as these are inaccessible to the vsini method. We present results from a study of the magnetic activity-rotation relation for a large sample of field M dwarfs for which we have measured rotation periods from MEarth and PTF programs (including many slow rotators; 50-150 days) and low-resolution spectroscopic observations from FLWO/FAST and SDSS. We quantify the magnetic activity of the stars using the chromospheric H-alpha emission line and find that there is a clear trend of decreasing activity with increased rotation periods for all M dwarf spectral types. In addition, a kinematic analysis of the three-dimensional space motions of the stars confirms that those with higher levels of magnetic activity are consistent with being younger than their less active (or inactive) counterparts.

We acknowledge MEarth funding from the Packard Fellowship for Science and Engineering and the NSF (AST-0807690).

313.03 – **Metallicities of M Dwarfs Targeted by the MEarth Transiting Planet Survey**

Elisabeth Rose Newton[1], J. Irwin[1], D. Charbonneau[1], Z. K. Berta[1], B. Rojas-Ayala[2], K. Covey[2], J. P. Lloyd[2]

[1]*Harvard University,* [2]*Cornell University.*
10:20 AM - 10:30 AM

M dwarf metallicities have traditionally been very difficult to measure and observers have turned to empirical calibrations employing M dwarfs in wide binaries with FGK stars, where the primary has a measured metallicity. Rojas-Ayala et al. (2010) developed an empirical calibration based on the equivalent widths of alkali metal lines in the near-IR and an index measuring effective temperature. We use this method to measure the metallicities of M dwarfs in the MEarth transiting planet survey. The MEarth project is photometrically monitoring 2000 of the nearest mid to late M dwarfs in the northern sky and will expand in the next year to include an additional 2000 stars in the southern hemisphere. We present a study of 200 MEarth targets for which we have obtained near-IR spectra with IRTF/SpeX and Magellan/FIRE. We have previously determined photometric rotation periods for 100 of these stars; the remaining targets have measured parallaxes placing them within 25pc. All of the stars in our sample are fully convective. We will discuss the physical properties of stars observed to date, including correlations between rotation period, galactic kinematics and metallicity.

The MEarth team acknowledges funding from the David and Lucile Packard Fellowship for Science and Engineering and from the National Science Foundation under grant number AST-0807690. ERN is supported by a National Science Foundation Graduate Research Fellowship.

313.04D – **Hiding in Plain Sight: Nearby Low Proper Motion Stars**

Adric R. Riedel[1], T. J. Henry[1], R. J. White[1], E. L. N. Jensen[2], I. Song[3], N. C. Hambly[4], RECONS

[1]*Georgia State Univ.,* [2]*Swarthmore College,* [3]*University of Georgia,* [4]*Royal Observatory, Edinburgh, United Kingdom.*
10:30 AM - 10:50 AM

Astronomers have always used high proper motion to locate the nearest stars, but a substantial fraction --- nearly 15% --- of all stars within 25 pc are expected to move more slowly than 180 milliarcseconds/yr, the canonical proper motion limit of classic surveys, such as Luyten's.

Using the SuperCOSMOS Sky Survey BRI plate magnitudes, 2MASS photometry, and a variety of color-based selection criteria, we have completed a reconnaissance of the southern sky for nearby LOW proper motion objects --- those moving more slowly than 180 milliarcseconds/yr. The results are fascinating: We find genuinely nearby stars that have been hiding in plain sight, with the three nearest at 7.9, 9.4, and 10.5 parsecs, moving at only 120, 64, and 37 mas/yr, respectively. We have also uncovered a population of nearby pre-main-sequence and ZAMS (Hyades age and younger) dwarfs of M spectral type for which we are collecting parallaxes and proper motions, and in a few cases, mapping the orbits of newly discovered binaries. We use the new astrometric information to estimate ages and determine the kinematic associations of these stars. This effort is helping to reveal the supposed 'missing' M dwarf populations of nearby moving groups.

This effort is supported by the NSF through grant AST-0908402 and via observations made possible by the SMARTS Consortium. Confirmation of binaries has been accomplished using HST's Fine Guidance Sensors.

313.05 – **A Uniform Asteroseismic Analysis of 22 Solar-type Stars Observed by Kepler**

Travis S. Metcalfe[1], S. Mathur[1]

[1]*NCAR.*
10:50 AM - 11:00 AM

Asteroseismology with the Kepler space telescope is providing not only an improved characterization of exoplanets and their host stars, but also a new window on stellar structure and evolution for the large sample of solar-type stars in the field. We perform a uniform analysis for 22 of the best and brightest asteroseismic targets observed for 1 month each during the first year of the mission, and we quantify the precision and accuracy of asteroseismic determinations of the stellar radius, mass, and age that are possible using various methods. We present the properties of each star in the sample derived from an automated analysis of the individual oscillation frequencies and other observational constraints using the Asteroseismic Modeling Portal (AMP), and we compare them to the results of model-grid-based methods that fit the global oscillation properties. We find that fitting the individual frequencies typically yields asteroseismic radii and masses to ~1% precision (respectively 2 and 5 times better than fitting the global oscillation properties), and ages to ~2.5% precision (nearly an order of magnitude improvement over grid-based methods). The absolute level of agreement between the results from different approaches is also encouraging, with model-grid-based methods yielding slightly smaller estimates of the radius and mass and slightly older values for the stellar age. The sample of targets for which this type of analysis is possible will grow as longer data sets are obtained during the remainder of the mission.

313.06 – **Chemical Abundances Of Carbon-enhanced Metal-poor Stars With X-shooter**

Catherine R. Kennedy[1], T. C. Beers[2], B. Nordstrom[3], C. Hansen[4]

[1]*Australian National University, Australia,* [2]*Michigan State University, JINA, NOAO,* [3]*Niels Bohr Institute, Copenhagen University, Denmark,* [4]*ZAH, University of Heidelberg, Germany.*
11:00 AM - 11:10 AM

We present abundances of carbon-enhanced metal-poor (CEMP) stars observed with the X-Shooter spectrograph on the ESO VLT. With broad wavelength coverage, spanning from near-UV to near-IR, these moderate resolution spectra are used to estimate CNO abundances and neutron-capture-element abundances for a sample of 27 metal-poor stars. With these estimates in hand, we classify each CEMP star according to its chemical signature. The classes of CEMP stars that we identify are suggestive of different mechanisms that gave rise to their carbon enhancements. We discuss the likely sites of carbon production associated with these types of stars.

This work was supported in part from grants AST 07-07776, as well as from PHY 02-15783 and PHY 08-22648; Physics Frontier Center/Joint Institute for Nuclear Astrophysics (JINA), awarded by the US National Science Foundation. This work was also supported in part by the Danish Natural Science Research Council.

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314 – Protoplanetary Disks

Oral Session – Room 18D – Wednesday, January 11, 2012, 10:00 AM - 11:30 AM

314.01D – **Magnetorotational-Instability-Driven Accretion in Protoplanetary Disks**

Xue-Ning Bai[1]

[1]*Princeton University.*
10:00 AM - 10:20 AM

Magnetohydrodynamic (MHD) turbulence driven by the magnetorotational instability (MRI) has long been considered as the most promising mechanism for transporting

angular momentum in accretion disks. In protoplanetary disks (PPDs), however, the gas dynamics is strongly affected by non-ideal MHD effects such as Ohmic resistivity, Hall effect and ambipolar diffusion (AD) due to its weak ionization level. Most MRI calculations for PPDs done so far consider only the Ohmic resistivity, while Hall and AD effects dominate the surface and outer regions of PPDs but remain poorly explored. We perform 3D unstratified shearing-box MRI simulations with AD using a variety of magnetic field geometries and AD coefficients. We find that angular momentum transport becomes inefficient when the neutral-ion collision frequency falls below the orbital frequency. Moreover, sustained MRI turbulence requires weak magnetic field in the AD dominated regime. We present a general framework that incorporate these constraints together to predict the MRI-driven accretion rate and the corresponding magnetic field strength in PPDs. Our results show that the MRI becomes very inefficient at the inner disk with optimistically predicted accretion rate at least one order of magnitude too small compared with typical observed accretion rates, while angular momentum transport by magnetized wind is likely to be a favorable alternative. On the other hand, for transitional disks, characterized by inner gaps or holes representing a later stage of PPD evolution, we find that MRI is able to drive sufficiently rapid accretion consistent with observations, and the presence of tiny grains even promotes accretion. This work is supported by NASA headquarters under NASA Earth and Space Science Fellowship awarded to XNB.

314.02D – **Observational Constraints on Grain Growth in Protoplanetary Disks**

Laura M. Perez[1]

[1]*California Institute of Technology.*
10:20 AM - 10:40 AM

The majority of young low-mass stars are surrounded by optically thick accretion disks. These circumstellar disks provide large reservoirs of material that will eventually be transformed into planetary systems. Theory and observations suggest that the earliest stage toward planet formation in a protoplanetary disk is the growth of particles, from sub-micron size grains to centimeter-sized pebbles. Observationally, grain growth can be inferred by measuring the spectral energy distribution at long wavelengths, which traces the continuum dust emission spectrum and hence the dust opacity.

I will present interferometric high-angular resolution observations from the Combined Array for Research in Millimeter-wave Astronomy (CARMA), the Expanded Very Large Array (EVLA), and the Submillimeter Array (SMA), that span more than an order of magnitude in wavelength (from sub-millimeter to centimeter wavelengths) and attain sub-arcsecond angular resolution. These observations constrain the radial distribution of the circumstellar material and characterize the radial variations on the dust opacity spectral slope, that may originate from particle growth in these circumstellar disks. I will present the most recent results of this observational program and compare with theoretical predictions of grain size evolution in protoplanetary disks.

314.03 – **Examining Tidal Interactions in Taurus Pre-Main Sequence Multiples: A Systematic Test of Tidal-Truncation Theory**

Robert J. Harris[1], S. M. Andrews[1]

[1]*Harvard University.*
10:40 AM - 10:50 AM

Most stars are born in multiple systems. Theory predicts that star-disk interactions in these systems preferentially strip circumstellar disk material away from the lower-mass companion, such that the ratio of the companion disk radius to orbital separation is set by the orbital parameters of the system. To test the theoretical predictions of these interactions, we have carried out a new, resolved 880 micron Submillimeter Array (SMA) imaging survey of young multiple star systems in Taurus (for stellar mass ratios > 0.1 and separations > 35 AU) to measure the key observables of star-disk interaction theory, i.e. circumstellar disk masses and radii as a function of orbital separation and stellar mass ratio. We discuss this survey and its implications for tidal-truncation theory

314.04 – **Spitzer Spectroscopy of Gas in T Tauri Disks**

Joan R. Najita[1], J. Carr[2], C. Salyk[1], K. Pontoppidan[3], G. Blake[4], E. van Dishoeck[5]

[1]*NOAO,* [2]*NRL,* [3]*STScI,* [4]*Caltech,* [5]*Leiden Observatory, Netherlands.*
10:50 AM - 11:00 AM

Emission from water and organic molecules is commonly found in Spitzer spectroscopy of T Tauri stars, with the emission likely arising from the inner few AU of the circumstellar disk. As they probe the inner planet formation region of the disk, these diagnostics offer the opportunity for new insights into planet formation processes and disk chemical evolution. I will describe some recent insights that have emerged from Spitzer spectroscopy of T Tauri stars.

314.05 – **Further Characterizing the Planet Forming Region Around V1331 Cyg**

Greg Doppmann[1], J. Najita[2], J. Carr[3], J. Graham[4]

[1]*Keck Observatory,* [2]*NOAO,* [3]*NRL,* [4]*UC Berkeley.*
11:00 AM - 11:10 AM

High resolution L-band (3.0-3.9 μm) spectra of young stars with circumstellar disks provide a key window for probing the physical conditions and pre-biotic chemistry within the inner disk region where terrestrial-like planets are thought to form. Rich with transitions due to water, OH, and key organic compounds of biological interest, L-band spectra at high resolution (R > 18,000) are critical to elucidate the properties of each molecular component present. Well-suited for this purpose, our NIRSPEC/Keck observations of V1331 Cyg, an intermediate mass young stellar object (spectral type A8-G5), show strong OH and water emission at 1500K. At R=24,000, our spectra resolve individual lines in the crowded emission spectrum that is dominated by water, and enable us to also characterize the accompanying OH emission. By comparing the observed spectra with synthetic disk models we (1) probe the nature of the accretion mechanism in the inner disk from the temperature, column density, and line broadening of the water emission that is present, (2) examine the disk photochemistry from the abundance ratio of OH to water, and (3) employ the new HITEMP line list to make empirical improvements to the water line list and thereby detect or set detection limits on organic emission (e.g., C_2H_2, HCN, C_2H_6, H_2CO, NH_3, and CH_4) that may underly the L-band water spectrum. Support for this research was provided in part by the NASA Origins of Solar Systems program NNH10A0061.

314.06 – **Protoplanetary Disk Masses In The Orion Nebula Cluster from the SMA**

Rita Mann[1], J. Williams[2]

[1]*National Research Council Canada, Canada,* [2]*Institute for Astronomy, Univ. of Hawaii at Manoa.*
11:10 AM - 11:20 AM

The formation of planetary systems is intimately connected to the properties of the circumstellar disks in which they are born. Disk studies to date have focused on regions like Taurus and Ophiuchus for their proximity, however, stars rarely form in such isolated environments. Most stars form in massive star forming regions and there is even clear evidence that our Sun formed near an OB association like that found in Orion. Using the Submillimeter Array (SMA), we surveyed 67 protoplanetary disks ("proplyds") at 850 microns in the Orion Nebula to determine their masses. The SMA, as the world's only sub-millimeter interferometer until ALMA, has been uniquely capable of detecting dust emission from the Orion proplyds, making these results the only successful measurements of disk masses in an OB association. These observations have revealed the range of influence of nearby massive stars on disk evolution and allowed us to answer the long-standing question about whether enough material remains in the Orion disks to potentially form Solar System analogs.

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315 – Magnetic Fields in the Formation of Stars and Protoplanetary Disks

Invited Session – Ballroom D – Wednesday, January 11, 2012, 11:40 AM - 12:30 PM

315.01 – **Magnetic Fields in the Formation of Stars and Protoplanetary Disks**

Susana Lizano[1]

[1]*Centro De Radioastronomia Y Astrofisica, Mexico.*
11:40 AM - 12:30 PM

I will discuss the role of magnetic fields in the collapse of dense cores to form stars and protoplanetary disks. I will highlight recent theoretical results that show how magnetic fields, with the magnitudes currently observed in molecular clouds, affect the evolution of these dense cores and protoplanetary disks. Decades ago Mestel and Spitzer pointed out that the magnetic flux must be dissipated at some point during the gravitational collapse of the cloud cores or the magnetic fields of young stars would be too large. It has been recognized recently that field freezing of magnetic fields also presents an obstacle to the formation of protoplanetary disks: magnetic braking by the strong field dragged during the collapse will prevent the formation of a centrifugally supported disk. Thus, non-ideal effects like Ohmic dissipation or ambipolar diffusion must set in at high densities o get rid of the excess magnetic flux in the star and prevent the catastrophic magnetic braking. Another important result is that realistic levels of disk magnetization left over during the protoplanetary disk formation will produce subkeplerian rotation of the gas. This effect makes it difficult to eject disk winds in cold accretion disks and affects planet migration. Finally, I will discuss the enhanced gravitational stability of magnetized accretion disks and its effect on planet formation.

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316 – NASA Town Hall

Town Hall – Ballroom E – Wednesday, January 11, 2012, 12:45 PM - 1:45 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.

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317 – NOAO Town Hall

Town Hall – Ballroom F – Wednesday, January 11, 2012, 12:45 PM - 1:45 PM

These are exciting times for NOAO, our user community, and our partners. Both new or improved optical spectrometers (Mayall/KOSMOS, Blanco/COSMOS, SOAR/Goodman; and soon LBT/MODS) and infrared spectrometers (Gemini/GNIRS, Gemini/FLAMINGOS-2; and soon LBT/Lucifer and Blanco/TripleSpec) are arriving at facilities with open access via NOAO. The world-class, wide-field optical imager (Blanco/DECam) will enable a major new survey (Dark Energy Survey). Plans are afoot for new access to non-NOAO facilities soon via ReSTAR-2. Looking to the future – a 5000-fiber optical spectrometer (Mayall/BigBOSS) has been proposed to enable another major new survey, NOAO is heavily involved in LSST development, and Gemini/NOAO consolidation is under active discussion. At the same time, NOAO faces increased scrutiny within the context of a NSF Astronomy portfolio review. That review may spark revolutionary change at your national observatory. Come join the NOAO Director and other NOAO staff at the annual NOAO Town Hall for a brief overview presentation and a question-and-answer session.

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318 – Energetic Binary Stars I

Oral Session – Room 12A – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

318.01D – **The Curious Case of LMXB 4U 1820-30: Resonant Trapping and Tidal Dissipation Rate of the White Dwarf Secondary**

Snezana Prodan[1], N. Murray[1]

[1]*CITA/ University of Toronto, Canada.*

2:00 PM - 2:20 PM

Low mass X-ray binary 4U 1820-30 is an 11-min period binary with two very interesting properties: a luminosity variation by factor of ~2 with a period of 170 days and a negative period derivative. It has been suggested that the 170-day period in the light curve of the low mass X-ray binary 4U 1820-30 arises from the presence of a third body with a large inclination to the binary orbit. We show that this long period motion arises if the system is librating around the stable fixed point in a deep resonance. We demonstrate that mass transfer drives the system toward this fixed point, and calculate, both analytically and via numerical integrations, that the period of libration is of order 170 days when the mutual inclination is near the critical value required to induce eccentricity oscillation by the third body. The non-zero eccentricity of the binary, combined with tidal dissipation, implies that the rate of change of the binary period would be slower than, or even of opposite sign to, that implied by standard mass transfer models. If the 170-day period results from libration, then, contrary to appearances, the orbital period of the inner binary is increasing with time; in that case we can obtain a lower limit on tidal dissipation factor Q of the white dwarf secondary for the fiducial eccentricity of the inner binary. It appears unlikely that the observed negative period derivative results from the smaller than expected (but positive) value of the period derivative combined with the previously suggested acceleration of the system in the gravitational field of the host globular cluster NGC 6624.

318.02D – **Powerful Jet-driven Outflows from Two Bright Microquasars, Circinus X-1 and Cygnus X-1**

Paul Sell[1], S. Heinz[1]

[1]*The University of Wisconsin-Madison.*

2:20 PM - 2:40 PM

We investigate the interaction of the jets from two bright microquasars, Circinus X-1 and Cygnus X-1, with the ISM. Our recent Chandra X-ray observations of Circinus X-1 reveal the first direct detection of an X-ray jet from a neutron star. We also see where the bipolar jet impacts the nearby ISM in terminating shock plumes that we refer to as "caps". We find that the caps are dominated by a cooled synchroton spectrum with a cooling time, $t_{cool} \sim 1600$ yr, suggesting that the jets are a fairly recent phenomenon. Our analysis of the caps also shows that the neutron star can produce jets as powerful and efficiently as black holes (3×10^{35} erg/s $< P_{jet} < 2 \times 10^{37}$ erg/s; $e_{jet} > 0.034\%$).

In the case of Cygnus X-1, we use X-ray and optical spectroscopic observations to probe the limb-brightened radio and optical shell where the jet of the microquasar seems to be driving shocks into a nearby HII region. With our Chandra X-ray observations, we place upper limits on the mass flow rate across the shock and thus on the velocity of the shell. We also acquired multi-object spectroscopic observations along the shell to constrain the density and temperature of the outflow. Our analysis of jet driven outflows from these two microquasars highlights the different dominant physical mechanisms involved in jet-driven, parsec-scale shocks in the ISM.

318.03 – **Long Term Fermi LAT Observations of LS I 61 303 and LS5039**

Richard Dubois[1], Fermi LAT Collaboration

[1]*SLAC National Accelerator Laboratory.*

2:40 PM - 2:50 PM

The Large Area Telescope (LAT) on the Fermi Gamma-ray Space Telescope has been observing the sky in gamma rays since August 2008. It scans the entire

sky above 20 MeV every 3 hours with unprecedented sensitivity in the high energy range, making it an ideal monitor for binary systems. 2.5 years of observations at GeV energies bring up new insights into LSI +61 303's behavior, notably variability in its base flux levels and orbital modulation. Additionally we will present an update on LS5039, which has been stable over the observation time.

318.04 – **A Giant Radio Flare from Cygnus X-3 with Associated Gamma-ray Emission**

Anna Szostek[1], S. Corbel[2], G. Dubus[3], Fermi LAT Collaboration, J. A. Tomsick[4]

[1]*Stanford University,* [2]*Universite Paris Diderot/CEA Saclay, France,* [3]*Laboratoire d'Astrophysique de Grenoble, Universite J. Fourier, France,* [4]*SSL/UC Berkeley.*

2:50 PM - 3:00 PM

With frequent flaring activity of its relativistic jets, Cygnus X-3 (Cyg X-3) is one of the most active Galactic microquasars. It is also the only Galactic black hole candidate with confirmed high energy gamma-ray emission thanks to detections by Fermi/LAT and AGILE. In early 2011 February, Cyg X-3 was observed to transit to a soft X-ray state, a period known to be associated with high energy gamma-ray emission. A giant (~20 Jy) optically thin radio flare marked the end of the soft state. Fermi/LAT observations (E > 100 MeV) revealed gamma-ray activity associated with the giant radio flare. In addition, the observations unambiguously showed that the gamma-ray emission is not exclusively related to the spectacular and rare giant radio flares. A 3-week period of gamma-ray emission was also detected earlier during soft state, when Cyg X-3 was weakly flaring in radio, with 15 GHz peak flux density of ~0.6 Jy. We present the results of a multi-wavelength campaign (which included data from OVRO, AMI, Ratan, RXTE/ASM, MAXI, Swift/BAT, Fermi/LAT), covering a period of the giant radio flare. We identify fluxes in radio and hard X-rays which could potentially be used as trigger criteria for further pointed observations in X-rays and other bands. JAT acknowledges partial support from NASA Fermi Guest Observer award NNX10AP83G and from NASA Astrophysics Data Analysis Program award NNX11AF84G. GD acknowledges support by the European Community contract ERC-StG-200911.

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319 – Surveys and Large Programs I

Oral Session – Room 18A – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

319.01 – **The Southern Hemisphere Standard Star Catalog of PreCam, the Precursor to the Dark Energy Survey**

Kyler Kuehn[1], Dark Energy Survey

[1]*Argonne National Laboratory.*

2:00 PM - 2:10 PM

The Dark Energy Survey (DES) will begin in 2012, and will use the Dark Energy Camera (DECam) to observe 5000 sq. deg. of the southern hemisphere in multiple

passbands, with the primary goal of constraining the Dark Energy equation of state. A 1/32-scale precursor camera (PreCam) was constructed as a testbed for DECam hardware and software, and for obtaining preliminary observations of the DES footprint. Of most benefit to DES--and to the broader astronomical community--is PreCam's catalog of southern hemisphere standard stars observed in g,r,i,z, and Y filters. We describe the current state of this catalog, along with other interesting results from PreCam observations. We conclude with a description of prospects for future additions and refinements to the present PreCam dataset, and its ultimate impact upon DES science.

319.02D – **AGILITE: An ATA Survey to Characterize the Population of Galactic Radio Transients and Variables**

Peter K. G. Williams[1], G. C. Bower[1]

[1]*UC Berkeley.*
2:10 PM - 2:30 PM

Systematic studies of transient and variable radio emission are a relative novelty. Searches for "slow" radio transients, sources that vary over timescales of days to months, have so far tended to focus on extragalactic fields. Many Galactic sources, however, vary on these timescales, including X-ray binaries, brown dwarfs, and several objects of unknown nature discovered in previous efforts. We present AGILITE, the ATA Galactic Lightcurve and Transient Experiment, an effort to characterize the population of Galactic radio transients and variables more fully. AGILITE has a large overall footprint (≈25 deg²), a substantial number of epochs (≈200), and a significant dedication of observatory time (≈1700 hr over two years), which make it sensitive to rare objects as well as variability on many timescales. We describe the AGILITE pipeline and the current status of the project. We discuss prospects for the complete survey as well as other applications of the dataset, such as large-scale mapping of extended radio emission in the Galactic Plane.

319.03 – **New Insights into Radio Transients from the Allen Telescope Array**

Steve Croft[1], G. C. Bower[1], D. Whysong[1], Allen Telescope Array Team

[1]*UC Berkeley.*
2:30 PM - 2:40 PM

Much of what we know about radio transients comes from follow-up observations of objects discovered at shorter wavelengths. In the last five years, however, archival studies have begun to discover statistically significant numbers of radio transients. Now a new generation of radio telescopes, as well as upgrades to older instruments, has the potential to find large numbers of these events. A key factor in the design of the Allen Telescope Array (ATA) was its ability to efficiently survey large areas of sky to search for variable and transient radio sources. We present results from the ATA 20-cm Survey (ATATS), a pilot 11-epoch survey of 700 sq. deg of sky at 1.4 GHz, and the Pi GHz Sky Survey (PiGSS), a survey which includes a two-epoch wide field (5000 sq. deg.) component, and also a total of ~450 repeated observations of four 10 sq. deg. deep fields. The ATA is opening new areas of rate -- sensitivity parameter space in the search for radio transients, and the lessons learned are valuable for the development of next generation surveys during the lead-up to the Square Kilometer Array.

319.04 – **Polarimetric Calibration of Mimir and the Galactic Plane Infrared Polarization Survey**

Dan P. Clemens[1], A. Pinnick[1], M. Pavel[1]

[1]*Boston Univ..*
2:40 PM - 2:50 PM

The methods and observations are described for the full field of view (FOV) polarimetric calibration of the Mimir near-infrared imaging polarimeter in support of the Galactic Plane Infrared Polarization Survey and other imaging polarimetric applications. Polarimetric calibration consisted of three major steps: (1) flat-fielding using in-dome images obtained with the half-wave-plate (HWP) oriented to the 16 position angles employed in polarimetric observations; (2) mapping and removing the remaining instrumental polarization via observations of unpolarized globular cluster stars; and (3) correcting the instrument zero-phase angle to equatorial and correcting for linear polarization efficiency, both using observations of polarimetric standard stars. For Mimir, the HWP-angle flat-fielding step reduced the first-order instrumental polarization to under 0.5% across the FOV. The 151 observations of eight globular clusters yielded over 40,000 stellar measurements for determining the 0.05-0.45% second-order instrumental polarization across the Mimir FOV to uncertainties of 0.02-0.04%. The 444 observations of 23 polarized standard stars allowed determination of observing run-based offset angles to 0.5 deg uncertainty and the polarization efficiency to be 91.1+/-0.4%. The observations of the standard stars, when fully corrected, showed superb agreement with published values of polarization percentage and position angle.

Additionally, the observations of four sky fields containing `primary' polarization standard stars were analyzed to yield 30 new `secondary' linear polarization standards. These are fainter than the primaries, allowing use with larger apertures and longer integration times. The secondary standards have polarization position angle uncertainties under 5 deg and range in degree of polarization from 0.40 to 8.52%.

Supported by NSF grants AST 06-07500 and 09-07790.

319.06 – **Campaigns to Monitor Predicted Mesolensing Events**

Rosanne Di Stefano[1], S. Lepine[2], J. Matthews[1]

[1]*Harvard-Smithsonian CfA,* [2]*American Museum of Natural History.*
3:00 PM - 3:10 PM

When a nearby high-proper-motion star moves in front of a crowded stellar field, there is a high probability that it will lens one of the background stars. Lensing events can, in fact, be predicted. This makes it important to answer the question: when a lensing event is predicted, how best to plan an observing campaign to study the event and extract the parameters of the lens? How can we use such campaigns to discover planets or to compute the probability that the lens star has planets? We will discuss the specific example of the mesolens VB 10, which will have lensed a background star in December of 2011. Although the predicted low magnification and the presence of the Sun near the event location will have made conditions less than ideal for the study of this event, constraints on planets may have been derived by the time of the talk. Whatever the results,we will discuss what we learned by planning for this first-ever predicted mesolensing event. We will discuss the prospects for future predictions of individual events and of statistical predictions of multiple high-probability events.

319.07 – **ChanPlaNS: The Chandra X-ray Observatory Planetary Nebula Survey**

Joel H. Kastner[1], R. Montez, Jr.[1], ChanPlaNS Team

[1]*RIT Center for Imaging Science.*
3:10 PM - 3:20 PM

We present preliminary results from the first systematic Chandra X-ray Observatory survey of planetary nebulae (PNe) in the solar neighborhood. The Chandra Planetary Nebula Survey (ChanPlaNS), which began with a 570 ks Chandra Cycle 12 Large Program targeting 21 high-excitation PNe within ~1.5 kpc of Earth, is intended to provide new insight into the late stages of stellar evolution, with particular emphasis on binary star astrophysics and stellar wind interactions. We are finding that the central stars of PNe commonly appear as X-ray-luminous point sources in Chandra imaging. Surprisingly, the vast majority of these central point sources display X-ray spectra that are quite hard relative to the photospheric emission expected from hot white dwarfs. The origin(s) of these hard X-ray excesses remains uncertain; we discuss a number of potential explanations, ranging from pure single-star to binary interaction processes. The ChanPlaNS survey is also clarifying the relationship between fundamental PN properties (such as age and morphology) and the presence (or absence) of diffuse X-ray emission from central star fast wind shocks (i.e., "hot bubbles"). These ChanPlaNS X-ray imaging spectroscopy results for both point-like and diffuse X-ray emission will be used to inform and refine models describing PN shaping mechanisms and, in particular, the role of binarity in determining PN structure and evolution. This research is supported via award number GO1-12025A 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.

320 – Dust, the ISM and Associated Topics

Oral Session – Room 19B – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

320.01 – **UV-Visible Laboratory Spectra Of Presolar Oxide And CAI Analogs: Corundum, Spinel, Hibonite, And Melilites**

Karly M. Pitman[1], A. M. Hofmeister[2], A. K. Speck[3]

[1]*Planetary Science Institute,* [2]*Washington University - St. Louis,* [3]*University of Missouri - Columbia.*
2:00 PM - 2:10 PM

There is a paucity of UV-visible wavelength spectra and optical (dielectric) functions for important interstellar and circumstellar dust species. Whereas the isotopic properties and infrared spectral signatures of some oxide compounds have been well studied in astronomy, it is critical to extend the wavelength coverage as shortward as possible to calculate the temperature of dust and properly account for the energy budget in radiative transfer calculations of many astronomical environments. In this work, we will present the spectral behavior of selected oxides that have been found as presolar grains or calcium-aluminum inclusions (CAIs) in meteorites, covering the mid-UV to HST wavelength range (λ =190-1100 nm). We focus on corundum (Al_2O_3), spinel ($MgAl_2O_4$), and hibonite ($(Ca,Ce)(Al,Ti,Mg)_{12}O_{19}$) as the main analogs to the phases occurring in CAIs within primitive chondritic meteorites that condensed from the early solar nebula. We also present new UV-vis data for Ca- and Al-endmember melilites, which are early (high-temperature/pressure) condensation sequence products. Whereas Mg and Fe silicates are expected to dominate if dust formation goes to equilibrium, the high-temperature Ca-Al condensates are important for non-equilibrium processes. Collectively, these new UV-vis data have potential applications for observational and modeling studies of red giants and supergiants, AGB stars, protoplanetary disks, and SN.

This work is supported through NSF AST-1009544.

320.02 – **FUV Signatures of Dusty Galactic Clouds**

Erika T. Hamden[1], D. Schiminovich[1]

[1]*Columbia University.*

2:10 PM - 2:20 PM

We describe a project to observe and model the FUV signatures of diffuse galactic clouds. IR-excess clouds identified by Desert et al. (1988) and cold cores identified by the early cold core catalogue (ECC) from the Planck collaboration (Planck Collaboration et al. 2011) are used to identify potential dusty clouds. The GALEX AIS survey data of these dusty clouds are compared to the 100 micron dust maps from Schlegel, Finkbeiner, Davis (1998). We are developing a cloud model to predict and characterize the FUV behavior of these clouds given their positions in the galaxy, dust composition, and other properties. This model uses galactic dust information derived from realistic Galactic models (3D), combined with Hipparcos stars to create a reasonably good simulation of the galaxy in dust and illumination. Small dusty clouds are placed throughout the model and the predicted reflected FUV light is measured using ray-tracing. We present the results of this model as they compare to existing FUV and dust emission.

320.03 – **Classical Novae Blow Smoke Rings: A DIRTY Approach to Modeling Dust Formation**

Jillian Bornak[1], T. E. Harrison[1], K. D. Gordon[2]

[1]*New Mexico State Univ.,* [2]*Space Telescope Science Institute.*

2:20 PM - 2:30 PM

Classical novae (CNe) are convenient objects for studying dust formation. While they are not the dust-producing workhorses that AGB stars are, CNe provide a way to study a single epoch of dust formation. Estimates of dust masses in some novae have implied a large portion (if not all!) of the gas is turned into dust, which is not physical. We propose for these objects the problem lies in estimating the dust mass. We present a new approach using the dust radiative transfer code DIRTY. We chose this code for its ability to model various geometries and for including the effects of scattered light and transient heating of small grains.

We have an extensive and unpublished time series of OIR photometry with select nights of spectroscopy for the dusty nova V868 Cen (Nova Cen 91). Our work is innovative for simultaneously modeling the optical (central engine) emission and the IR (dust shell) emission, whereas previous studies have only modeled the IR emission, allowing us to account for ``contamination'' of short-wavelength IR by scattered optical light.

Our initial models used the simplest geometry, a spherical shell either homogeneous or ``clumpy''. While the spherical shell model could fit individual nights, it could not match the temporal evolution of the nova. Multiple studies of gas emission line profiles indicate that CNe ejecta shells have an ellipsoidal geometry with equatorial, tropical, and polar overdensities. We find that a torus model is a better fit for single nights of data as well as matching the temporal evolution of the nova. We present our results showing the formation, growth, and destruction of dust grains. We show importance of geometry on dust mass estimates and take the first steps to determine the physical location of dust formation in CNe.

320.04 – **Carbon Dust Production in Nearby Dwarf Spheroidal Galaxies**

Gregory C. Sloan[1], A. A. Zijlstra[2], E. Lagadec[3], M. Matsuura[4], K. E. Kraemer[5], M. A. T. Groenewegen[6], I. McDonald[2], J. T. van Loon[7], J. Bernard-Salas[8], P. R. Wood[9]

[1]*Cornell Univ.,* [2]*Univ. Manchester, United Kingdom,* [3]*European Southern Obs., Germany,* [4]*Univ. Coll. London, United Kingdom,* [5]*Boston Coll.,* [6]*Royal Obs. Belgium, Belgium,* [7]*Keele Univ., United Kingdom,* [8]*IAS, France,* [9]*Australian National Univ., Australia.*

2:30 PM - 2:40 PM

Infrared spectra from the Spitzer Space Telescope reveal significant quantities of dust produced in the outflows from carbon stars in the Sculptor, Fornax, and Leo I dwarf spheroidal galaxies. Three carbon stars in the Carina dwarf spheroidal appear to be relatively dust free. Many of the sources are known long-period variables, and comparisons of how the quantity of dust varies with pulsation period show no dependence on metallicity, as previously found when studying carbon stars in the more metal-rich Magellanic Clouds and the Milky Way. The previous comparisons revealed that as metallicity decreases, SiC dust emission features generally grow weaker while acetylene absorption bands grow stronger. Our new data also follow these trends and extend them to metallicities with [Fe/H] as low as about -1.4.

320.05 – **Probing Tiny Scale Structures Of The Ism Using H I Absorption Spectra**

Nirupam Roy[1], A. H. Minter[1], W. M. Goss[1], C. L. Brogan[1], P. Dutta[2], J. N. Chengalur[2], T. J. W. Lazio[3]

[1]*National Radio Astronomy Observatory,* [2]*National Centre for Radio Astrophysics, India,* [3]*Jet Propulsion Laboratory.*

2:40 PM - 2:50 PM

The interstellar medium is known to have significant structures over a wide range of scales. These structures are generally interpreted as the signature of turbulence in the ISM. Here we present the results from high resolution observation of HI absorption towards 3C138 and the estimated structure function of the tiny scale opacity fluctuations from the combined VLA, MERLIN and VLBA data. The structure function is well represented by a power law with power law index of 0.33 over 5 - 100 AU. The amplitude of the structure function suggests significantly higher opacity fluctuations at these scales than the expected value from the extrapolation of observations at larger scales. This indication of the presence of rich tiny scale structures may be used to constrain models of turbulent ISM.

320.06 – **First Light: Physics of Early Star Formation from the Local Universe**

Eric W. Pellegrini[1], R. Porter[2], P. Stancil[2]

[1]*University of Michigan,* [2]*University of Georgia Athens.*

2:50 PM - 3:00 PM

We present detailed theoretical spectra of the earliest star forming regions. Improving on the spherically symmetric shell with a single ionization potential and density, we form a nebular template using the recently derived 3-D structure and density of 30 Doradus. Using CLOUDY, we illuminate our complex cloud with an SED of metal free stars, and vary the elemental and dust abundances from Z=-1 to -6. We solve for the physical condition of the gas as radiation is absorbed and reprocessed across the many different $H^+/H^0/H_2$ interfaces forming the entire nebula. We solve for abundance and ionization states of all elements, as well as the abundance of 100's of molecular species which form after the ionizing radiation has been absorbed. We produce globally average, rest-frame synthetic spectra from 10^{-3} to 10^{6}μm allowing us to create empirically motivated diagnostics of early enrichment and stellar feedback for JWST and ALMA. This includes broad continuum features AND the atomic and molecular emission from the entire complex. With the structural and feedback details revealed in these models, there exists an unprecedented opportunity to illustrate the most promising observational strategies for new observatories peering back to first light. Future efforts to observe and create more templates using nearby HII regions will expand the modeled parameter space. These templates will also serve as an alternative to the current sub-grid structure of HII regions in cosmological simulations.

320.07 – **WISE Observations of The Evolution of Massive Star Forming Regions**

Xavier Koenig[1], D. Leisawitz[1], D. Benford[1], L. Rebull[2], D. Padgett[1], R. Assef[3]

[1]*NASA Goddard Space Flight Center,* [2]*Spitzer Science Center/Caltech,* [3]*Jet Propulsion Laboratory, Pasadena.*

3:00 PM - 3:10 PM

We present the results of a mid-infrared survey of 11 outer Galaxy massive star forming regions and 3 open clusters with data from the Wide-field Infrared Survey Explorer (WISE). Using a newly developed photometric scheme to identify young stellar objects (YSOs) and exclude extragalactic contamination, we have studied the distribution of young stars within each region. These data tend to support the hypothesis that latter generations may be triggered by the interaction of winds and radiation from the first burst of massive star formation with the molecular cloud material left over from that earlier generation of stars. We dub this process the 'fireworks hypothesis' since star formation by this mechanism would proceed rapidly and resemble a burst of fireworks. We have also analyzed small cutout WISE images of the structures around the edges of these massive star forming regions. We observe large (13 pc size) pillar and trunk-like structures of diffuse emission nebulosity tracing excited PAH molecules and small dust grains at the perimeter of the massive star forming regions. These structures contain small clusters of emerging Class I and Class II sources, but some are forming only a single to a few new stars.

320.08 – **Diffuse UV Background Radiation**

Richard Conn Henry[1], J. Murthy[2]

[1]*Johns Hopkins Univ.,* [2]*Indian Institute of Astrophysics, India.*

3:10 PM - 3:20 PM

The diffuse UV sky is expected to glow with significant amounts of starlight that is scattered from the interstellar dust. The albedo and scattering pattern of the dust in the ultraviolet are both well established, and are both fairly independent of wavelength from 912 Å to 3000 Å. We present 1943 Voyager spectra of the diffuse cosmic background radiation from 500 Å to 1200 Å, and we compare their brightnesses, and their distribution on the sky, to those observed (Murthy et al., ApJ 724, 1389, 2010) from the GALEX mission at longer wavelengths (1530 Å). Significant differences appear, suggesting that background radiation components in addition to dust-scattered starlight may be present in both spectral regions.

320.09 – **Detecting Lyman Alpha Emission from Circum-Galactic and Intergalactic Gas with the Palomar Cosmic Web Imager**

Christopher D. Martin[1], M. Matuszewski[1], P. Morrissey[1], S. Rahman[1], A. Moore[1]

[1]*Caltech.*
3:20 PM - 3:30 PM

We have used the Palomar Cosmic Web Imager, an integral field spectrograph to search for faint Lyman alpha emission from the Circum-Galactic Medium, Circum-QSO Medium, and Intergalactic Medium. In this talk we report on progress and possible detections.

321 – AGN, QSO, Blazars VI

Oral Session – Room 17A – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

321.01 – **A New Determination Of The High-redshift Quasar Luminosity Function To I~25 In The COSMOS Field**

Daniel Masters[1], P. Capak[2], M. Salvato[3], F. Civano[4], B. Mobasher[1], T. Nagao[5], J. Trump[6], M. Elvis[4], N. Scoville[2]

[1]*University of California, Riverside,* [2]*California Institute of Technology,* [3]*Max Planck Institute for Plasma Physics, Germany,* [4]*Harvard,* [5]*Ehime University, Japan,* [6]*University of California, Santa Cruz.*
2:00 PM - 2:10 PM

We investigate the high-redshift quasar luminosity function down to I~25 in the Cosmic Evolution Survey (COSMOS) field, using a selection that we demonstrate to be close to 100% complete for Type-1 quasars at the redshifts of interest. Careful analysis of the extensive COSMOS photometry and imaging data allows us to remove stellar and low-redshift contaminants from our candidate list. We find 133 likely quasars at z>3.1, 39 of which have prior spectroscopic confirmation. These confirmed and likely quasars are used to compute the rest-frame UV QLF in the redshift bins $3.1 < z < 3.5$ and $3.5 < z < 5$. We find strong evolution of the faint end of the QLF between these redshifts, with the space density of faint quasars decreasing by roughly a factor of four from z~3.2 to z~4. This demonstrates that the population of faint quasars is decreasing rapidly with redshift above z~3, in accord with what has been found for more luminous optical and X-ray quasars. We compare the rest-frame UV luminosity functions found here with the X-ray luminosity function at $z > 3$, and find that they evolve similarly between z~4 and z~3.2; however, the different normalizations imply that roughly 75% of X-ray bright active galactic nuclei (AGN) at z~3-4 are optically obscured. The implications of these results for the contribution of quasars to reionization are discussed.

321.02D – **Understanding the Nature of Blazars High Energy Emission with Time Dependent Multi-zone Modeling**

Xuhui Chen[1], G. Fossati[1]

[1]*Rice University.*
2:10 PM - 2:30 PM

In this thesis we present a redeveloped time-dependent multi-zone radiative transfer code and its applications to study the multiwavelength emission of the blazars. The multiwavelength variability of blazars is widely believed to be a direct manifestation of the formation and propagation of relativistic jets, and hence the related physics of the black hole - accretion disk - jet system. However, the understanding of these variability demands highly sophisticated theoretical analysis and numerical simulations. Especially, the inclusion of the light travel time effects(LTTEs) in these calculations has long been realized important, but very difficult. The code we redeveloped couples Fokker-Planck and Monte Carlo methods, in a 2 dimensional (cylindrical) geometry. For the first time all the LTTEs are fully considered, along with a full, self-consistent treatment of Compton cooling, which depends on the LTTEs.

Using this code, we studied a set of physical processes that can be relevant to the variability of blazars, including electron injection and escape, radiative cooling, and stochastic particle acceleration. Our comparison of the observational data and the simulation results revealed that a combination of all those processes is needed to reproduce the observed behaviors of the emission of blue blazars (the blazars that emit at relatively high frequency). The simulation favors that the high energy emission at quiet and flare stages comes from the same location. we have deduced the physical parameters for the jet of one of the brightest blazar Mrk 421.

We have further modeled FSRQ PKS 1510-089. External radiation, which comes from the broad line region(BLR) or infrared torus, and illuminates the jet, is included in the model. The results confirm that external Compton (EC) model can adequately describe the emission from red blazars. The BLR emission is favored as the source of external radiation field. Parameters for PKS 1510-089 are also deduced.

321.03D – **Studying LLAGN Accretion Disks through GRMHD, Monte Carlo Radiative Transport, and Shearing Box Simulations**

Guy L. Hilburn[1]

[1]*Rice University.*
2:30 PM - 2:50 PM

Research has been conducted using a suite of modeling codes to study LLAGN accretion disks, specifically for Sagittarius A* and M87's core. These include a GRMHD accretion flow evolver, Monte Carlo radiation transport code, and localized shearing box simulations. Modifications to these codes will be discussed, which make them particularly applicable to these types of sources. Results of interest regarding large scale flaring mechanisms in AGN disks, as well as kinetic scale particle heating methods, will be discussed and analyzed. Specifically, we cite global density changes due to mass accretion rate variations as the likely source of LLAGN flaring behavior, while double-Maxwellian electron distributions heated by magnetic reconnection may explain the high energy emissions of these accretion disks.

321.04 – **Sgr A* X-ray Visionary Project --- The First High Resolution X-ray Spectrum of Sgr A* and the Central Parsec**

Frederick K. Baganoff[1], M. A. Nowak[1], S. Markoff[2], Sgr A* XVP Collaboration

[1]*MIT Kavli Institute for Astrophysics and Space Research,* [2]*API, University of Amsterdam, Netherlands.*
2:50 PM - 3:00 PM

Over the past dozen years, Chandra has performed extensive imaging spectroscopy of Sgr A* and its environment. The images, photometry, light curves and CCD-quality spectra of Sgr A* have revolutionized our understanding of ultra-sub-Eddington accretion onto our galaxy's supermassive black hole/quiescent AGN. In 2012, we will take these observations to the next level with an approved Chandra X-ray Visionary Project (XVP) to perform a 3-Ms HETG exposure to spatially and spectrally resolve the accretion flow within the Bondi radius of Sgr A*. This will provide the first high spectral resolution data on Sgr A* and diffuse emission from the central parsec of the galaxy. The spectrum will measure the energy and velocity width of the known Fe line from matter within the Bondi radius. It will also detect plasma line emission (e.g., Si & S), if present at levels predicted by RIAF models. Polarization measurements suggest most of the matter crossing the Bondi radius does not reach the event horizon. Understanding the dynamics and thermal structure of this plasma will tell us how this matter flows in and how much and where some of it flows back out. We will present a detailed simulation of the expected spectrum, and discuss how it relates to other LLAGN as a function of accretion rate. This project will permit extensive multiwavelength monitoring of Sgr A* flares that will provide stringent broadband spectral and temporal constraints on 3D GRMHD simulations of the Sgr A* accretion flow and its flaring activity. It will also produce light curves with increased cadence of faint X-ray transients, placing further constraints on the population of stellar remnants near Sgr A*. We are currently proposing for ground-based monitoring using observatories in the radio through gamma-rays. Absolutely no other current or planned X-ray mission can perform this science.

321.05D – **Correlated Radio And Gamma-ray Variability Of Blazars With The Ovro 40 Meter Telescope Monitoring Program And Fermi-LAT**

Walter Max-Moerbeck[1]

[1]*California Institute of Technology.*
3:00 PM - 3:20 PM

Blazars are powerful, variable emitters from radio to gamma-ray wavelengths. Their double-peaked spectral energy distribution can be explained as synchrotron emission at low energies and as inverse Compton emission at high energies. This general picture is not free of uncertainties and many open issues remain on the relationship between the low and high energy emission. Two related questions are: which radio blazars are gamma-ray emitters? and where is the gamma-ray emission being produced, close to black hole/accretion disk or in the jet as the radio band emission?. To make progress on these questions we have embarked on a flux density monitoring program at 15 GHz using the Owens Valley Radio Observatory 40 meter Telescope. The program started in mid 2007 with a sample of candidate gamma-ray blazars and currently about 1600 sources are observed twice per week. Here we present a description of this monitoring program along with results on the study of correlated time variations between radio and gamma-ray emission for the sources detected with the LAT instrument on board the Fermi Gamma-ray Space Telescope. The existence of correlated variability can be interpreted as an indication of common spatial location for the radio and gamma-ray emission, making the evaluation of its statistical significance a key goal of our program. A study of the statistical significance of these cross-correlations is presented along with a discussion of the Monte Carlo simulations used to evaluate them. More information about the conditions on the radio emission zone can be obtained through polarization monitoring which tells us about the configuration of the magnetic fields on the emission zone. To study radio polarization variability we are building KuPol, a radio polarization receiver for the 12 to 18 GHz band. A description of its capabilities and progress report will be given.

321.06 – **Morphologies And SEDs Of Low-redshift Low-ionization Broad Absorption Line QSOs**

Mariana S. Lazarova[1], G. Canalizo[1], M. Lacy[2], A. Sajina[3]

[1]*University of California, Riverside,* [2]*NRAO,* [3]*Tufts University.*

3:20 PM - 3:30 PM

We present optical and infrared HST/WFC3 images and Spitzer IRS spectra and MIPS photometry of a large volume-limited sample of 22 SDSS-selected Low-ionization Broad Absorption Line QSOs (LoBALs) at $0.5 < z < 0.6$. Previous studies of LoBALs show that their host galaxies tend to be ultraluminous infrared galaxies (ULIRGs) that are undergoing mergers and that have young stellar populations. We test the hypothesis that LoBALs are a transition phase from dust-embedded, ultra-luminous infrared QSOs toward unobscured type-1 QSOs by studying their morphologies for signs of recent tidal interaction and estimating star formation activity from their far-infrared SEDs. Our results show that, while the majority of the LoBALs are similar to type-1 QSOs in terms of their mid- and far-infrared properties, at least 20%, and as many as 60%, of the LoBALs are characterized by higher infrared luminosities typical of ULIRGs and star formation rates ~150-300 solar masses per year. Most of the LoBALs show apparent signs of tidal disturbance. We model the 2D host galaxy profiles with GALFIT and subtract simple bulge and disk models to reveal any fine structure, relic of past merger event. We correlate the morphologies and the merger stages with infrared luminosities, star formation rates, and mid-infrared spectral properties of this sample from Spitzer data. The unusually high fraction of LoBALs with high infrared luminosities and host galaxies showing signs of tidal interaction, in principle, fits the evolutionary paradigm, implying that LoBALs are rapidly transitioning from a ULIRG phase to a more quiescent phase with star formation activity typical of type-1 QSOs.

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322 – Evolution of Galaxies VI

Oral Session – Room 19A – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

322.01 – **Probing Galactic-Scale Outflows and Co-Rotating Halo Gas Towards a Compact Massive Galaxy**

Aleksandar M. Diamond-Stanic[1], A. Coil[2], J. Moustakas[2], C. Tremonti[3], R. Hickox[4], A. Mendez[2], A. Robaina[5], G. Rudnick[6], P. Sell[3]

[1]*CGE Fellow, University of California, San Diego,* [2]*University of California, San Diego,* [3]*University of Wisconsin,* [4]*Darthmouth College,* [5]*University of Barcelona, Spain,* [6]*University of Kansas.*

2:00 PM - 2:10 PM

The interplay between inflows and outflows of gas around galaxies has wide-ranging implications for galaxy evolution. We present results for a serendipitous background / foreground galaxy pair based on HST/WFC3 imaging, Keck/HIRES spectroscopy, and GALEX--Spitzer/IRAC photometry. The background galaxy is a massive (stellar mass ~ 10^{11} solar masses) post-starburst galaxy at $z=0.71$ with an extremely compact morphology (effective radius ~ 0.15 kpc) and an extreme outflow (velocity ~ -2500 km/s) traced by Mg I, Mg II, Fe II, and Mn II absorption lines. The depth of the Mg II absorption lines show that the outflowing gas covers the entire galaxy at v ~ -2500 km/s with additional optically thick, smaller covering factor gas extending to -3000 km/s. These results suggest a picture where a recent, highly dissipative merger event formed a compact starburst that launched an energetic, galaxy-wide outflow. The foreground object is an ~L* disk galaxy at $z=0.41$ for which we detect Mg II and Fe II absorption lines at a ~30 kpc impact parameter. These absorption lines are offset from the foreground galaxy redshift by ~200 km/s, consistent with an extension of the galaxy's rotation curve and consistent with theoretical predictions for inflowing gas that co-rotates in the galaxy halo before falling onto the galaxy disk. We discuss the implications of these results for models of gas accretion and feedback.

322.02D – **Mass and Environment as Drivers of Galaxy Evolution: Simplicity and its Consequences**

Yingjie Peng[1]

[1]*ETH Zurich, Switzerland.*

2:10 PM - 2:30 PM

The galaxy population appears to be composed of infinitely complex different types and properties at first sight, however, when large samples of galaxies are studied, it appears that the vast majority of galaxies just follow simple scaling relations and similar evolutional modes while the outliers represent some minority. The underlying simplicities of the interrelationships among stellar mass, star formation rate and environment are seen in SDSS and zCOSMOS. We demonstrate that the differential effects of mass and environment are completely separable to $z \sim 1$, indicating that two distinct physical processes are operating, namely the "mass quenching" and "environment quenching". These two simple quenching processes, plus some additional quenching due to merging, then naturally produce the Schechter form of the galaxy stellar mass functions and make quantitative predictions for the inter-relationships between the Schechter parameters of star-forming and passive galaxies in different environments. All of these detailed quantitative relationships are indeed seen, to very high precision, in SDSS, lending strong support to our simple empirically-based model. The model also offers qualitative explanations for the "anti-hierarchical" age-mass relation and the alpha-enrichment patterns for passive galaxies and makes some other testable predictions such as the mass function of the population of transitory objects that are in the process of being quenched, the galaxy major- and minor-merger rates, the galaxy stellar mass assembly history, star formation history and etc. Although still purely phenomenological, the model makes clear what the evolutionary characteristics of the relevant physical processes must in fact be.

322.03 – **Thinking Outside of the Box: First Light of the Millennium Run Observatory**

Roderik Overzier[1], G. Lemson[2], B. Henriques[2], R. Angulo[2]

[1]*University of Texas at Austin,* [2]*Max-Planck-Institute for Astrophysics, Germany.*

2:30 PM - 2:40 PM

We will introduce the Millennium Run Observatory (MRO), a unique project that is narrowing the gap between cosmological simulations and real observations. Key to this project is a new post-processing method applied to the Millennium Run dark matter simulations and semi-analytic galaxy models that allows us to generate highly realistic multi-wavelength data sets in the observer's frame. Different from most model-data comparisons performed in the literature today, the MRO produces data analogous to real telescope data. These virtual observations can be analyzed using the exact same methods and tools that are typically applied to real data, leading to a much better understanding of both the observations and simulations. We will demonstrate the power of this true "virtual observatory" by analyzing detailed simulated and real data sets probing the evolution of galaxy populations in, e.g., the UDF and the on-going multicycle HST treasury program CANDELS and in galaxy clusters at high redshift.

* This work was supported by Advanced Grant 246797 "GALFORMOD" from the European Research Council.

322.04D – **Exploring The Gas Cycle In High-redshift Galaxies: A Joint Effort Of Theory And Observations**

Michele Fumagalli[1]

[1]*UCSC.*

2:40 PM - 3:00 PM

The evolution of high-redshift galaxies is regulated by the balance between the inflow of fresh fuel for star formation and the outflow of metal-polluted material from star forming regions. Hydrodynamic cosmological simulations indicate that galaxies at high redshifts are fed by extended streams of cold gas in a smooth component and in merging satellites, but direct evidence of this mode of accretion is lacking. To investigate the signatures of these "cold streams" in observations, we have studied the Lyman-α emission and hydrogen absorption properties in galaxies simulated at high-resolution, using state-of-the-art radiative transfer codes. I will present these model predictions and I will compare and contrast results of simulations with observations of high-redshift Lyman break galaxies. I will also discuss the prospects of mapping the circumgalactic medium with absorption line systems and present preliminary results from ongoing observations.

322.05D – **Spitzer Irac Identification Of Herschel-atlas Spire Sources**

Sam Kim[1], J. Wardlow[1], A. Cooray[1], H-ATLAS team

[1]*UC Irvine.*

3:00 PM - 3:20 PM

We use spitzer IRAC to identify counterparts of sources selected with Herschel-SPIRE at 250, 350 or 500 micron in the Herschel Astrophysical Terahertz Large Area Survey (H-ATLAS). The IRAC catalogs are 50% complete to 22.5 and 22.2 AB magnitudes at 3.6 and 4.5 micron, respectively, and cover ~ 0.4 deg^2 of the H-ATLAS Science Demonstration Phase (SDP) field. Using a likelihood ratio analysis that accounts for the separation of SPIRE and IRAC centroids and the difference in the magnitude distribution of IRAC sources, we identify 144 reliable IRAC counterparts to 159 SPIRE-selected sources with overlapping IRAC coverage. We find that the SPIRE galaxies are redder than the field population at 3.6 and 4.5 micron and we use this property to identify 25 counterparts of 13 more SPIRE sources. The IRAC identification rate of 91% is significantly higher than has been demonstrated with wide-field ground-based optical and near-IR imaging of Herschel fields. While 33 of the identified counterparts have either photometric or spectroscopic redshifts, the galaxies undetected with ground-based optical data and without redshifts mostly have IRAC color [3.6]-[4.5]>0 and are likely to be at $z > 1$.

322.06 – **A Tale of Giants and Dwarfs: How the Red Sequence in Clusters Grew Over The Last 9.5 Gyr.**

Gregory Rudnick[1], K. Tran[2], C. Papovich[2]

[1]*University of Kansas,* [2]*Texas A&M University.*

3:20 PM - 3:30 PM

Understanding how star formation was turned off in galaxies over time and how these

passive galaxies then evolve is a major focus of galaxy evolution studies. Equally important is uncovering what role environmental processes play. Here we discuss the evolution of the red sequence in galaxy clusters over the past 9.5 Gyr of cosmic time, as revealed by deep YJK imaging with HAWK-I/VLT of a confirmed massive cluster at z=1.62. We use these data to measure the luminosity function (LF) of red sequence galaxies and chart the growth of the passive sequence. We compare the shape of the LF and the total light on the red sequence in the z=1.62 cluster with clusters at 0.4<z<0.8 from the ESO Distant Cluster Survey (EDisCS) and at z=0 from the SDSS. At z=1.62 we find a downturn in the LF at faint magnitudes consistent with seen at z=0.7 in EDisCS clusters. Interestingly, there is an apparent deficit of bright red galaxies in the z=1.62 cluster when compared to likely descendant clusters at lower redshift. After correcting for the evolving mass to light ratio, we find that the total amount of stellar mass on the red sequence increases rapidly from z=1.62 to z=0.7 and then increases more slowly to z=0. We will discuss scenarios for how the rapid growth in the total light over a period of 3.2 Gyr can be reconciled with the lack of evolution in the shape of the luminosity function. One possibility is that galaxies are added to the red sequence, but that other processes, e.g. dry merging, must be at play to explain the lack of evolution in the LF shape and to populate the bright end. At z<0.7 the amount of merging in the deep cluster potential well decreases and the LF shape begins to rapidly evolve.

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323 – Spiral Galaxies II

Oral Session – Room 18B – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

323.01 – **The Role of Large-scale Bars on Central Star Formation and AGN Activity**

Seulhee Oh[1], K. Oh[1], S. K. Yi[1]

[1]*Yonsei University, Korea, Republic of.*

2:00 PM - 2:10 PM

Galactic bars efficiently drive outer gas to the nuclear region of galaxies, and so they are often suspected to trigger central star-formation and active galactic nuclei (AGN) activities. However, the current status on this issue based on empirical studies is unsettling, especially on AGN. We investigate this question based on the Sloan Digital Sky Survey (SDSS) Data Release 7. Late-type galaxies are visually selected from the nearby ($0.01 < z < 0.05$) bright ($Mr < -19$) database. Among 6,658 late-type sample, we found 36% of galaxies to have a bar. Bars are found to be more common in galaxies with earlier morphology. Parameter-based selections would miss a large fraction of barred galaxies of early morphology, and so selection criteria become critical. Multiple factors (bar frequency, stellar mass, black-hole mass, gas contents, etc.) seem to contribute to bar effects on star formation or AGN in intricate manners. In the hope of breaking these degeneracies, we inspect bar effects for fixed galaxy properties. Bar effects on central star formation seem higher in redder galaxies. Bar effects on AGN, on the other hand, are higher in less massive galaxies. These effects seem more pronounced with increasing relative bar length. Our results imply that a large-scale bar can be a channel of gas inflow as expected, and the infalling gas activates both central star-forming and AGN activities under certain conditions. A careful sampling strategy and degeneracy-breaking analysis are necessary to find them.

323.02D – **Formation and Evolution of Circumnuclear Starburst rings**

Tessel Van Der Laan[1], E. Schinnerer[1], S. Garcia-Burillo[2], F. Combes[3], T. Boeker[4], E. Emsellem[5], F. Boone[6], G. Dumas[7], L. Hunt[8]

[1]*MPIA, Germany,* [2]*OAN, Spain,* [3]*LERMA, France,* [4]*ESA ESTEC, Netherlands,* [5]*ESO, Germany,* [6]*Université de Toulouse, France,* [7]*IRAM, France,* [8]*INAF, Italy.*

2:10 PM - 2:30 PM

The secular evolution of galaxies is especially noticeable in their central kiloparsecs where the dynamical timescales are much shorter than at larger radii. Large scale bars and circumnuclear (resonance) rings are important features that drive this evolution. Circumnuclear rings are believed to be very effective barriers for gas inflow to the nucleus and can thus contain large amounts of gas. In the central kiloparsec, most gas is in molecular form. The high densities that molecular gas can reach in these rings, leads to rapid and extreme star formation events. The total effect circumnuclear starburst rings have on secular evolution depends on the longevity of the rings and their ability to replenish themselves with gas.

Here, we investigate the circumnuclear starburst rings in two nearby barred spiral galaxies, NGC 5248 and NGC 6951. We will present high resolution CO emission line observations of molecular gas in and around the circumnuclear rings in both galaxies in combination with HST imaging and optical integral-field spectroscopy data probing the stellar population in the central kiloparsec. The observed gas kinematics and derived age distribution of the stellar populations of the rings provide insights into their formation/evolution. First results show preferred locations for the young stellar populations, related to the locations where the large scale bar connects with the ring via its gas- and dust-lanes. We also obtain an estimate for the lifetime of the ring from the oldest observed stellar populations (~2Gyr), which implies a minimum lifetime for the large scale bar as well.

323.03 – **Pitch Angle Restriction in late Type Spiral Galaxies.**

Maria de Los Angeles Perez Villegas[1], B. Pichardo[1], E. Moreno[1], A. Peimbert[1], H. M. Velazquez[1]

[1]*IA-UNAM, Mexico.*

2:30 PM - 2:40 PM

With a set of models for low bulge mass spiral galaxies (late type as defined by Hubble classification), that include a novel 3-D self-gravitating potential based on density distribution for spiral arms (PERLAS), instead of the usual 2D approximations (cosine potentials), we have analyzed the galactic orbital dynamics as a function of the pitch angle (going from 10 to 60 degrees). We found, from an extensive orbital study in phase space, that for late spiral galaxies, with angles lager than ~50 deg, chaos may become pervasive, having the effects of destroying the order phase space surrounding the main stable periodic orbits that sculpt spiral arms and even destroying them. This result is in good agreement with observations of late spiral galaxies, where the maximum observed pitch angle is about 50 degrees.

323.04D – **Observational Evidence Against Rigid Spiral Patterns in Galaxies**

Jason Speights[1], D. Westpfahl[1]

[1]*New Mexico Tech.*

2:40 PM - 3:00 PM

Spiral arm pattern speeds are measured for a small sample of nearby spiral galaxies to determine if their patterns are rigidly rotating waves. The method for measuring the pattern speed consists of solving the Tremaine - Weinberg equations for a pattern speed that is allowed to vary with radius. To determine if a pattern is rigidly rotating, the goodness of fit for a solution using a constant pattern speed model is compared with the goodness of fit for solutions using alternative models that are functions of radius. The alternative models provide a better fitting solution in every case. Plots of the alternative models more closely resemble the speed of the material than they do the speed of a rigidly rotating wave. Plots of the alternative models also show that there are no clear indications of unique locations for wave resonances that are predicted by some theories. These results imply that spiral patterns are recurring transient features because this would explain the abundance of spiral patterns that are observed while avoiding the winding dilemma for material arms.

323.05 – **Cosmological Simulations: The Effect Of ISM Heating And Cooling On The Central Mass Distribution Of Spiral Galaxies**

Charlotte Christensen[1]

[1]*University of Arizona.*

3:00 PM - 3:10 PM

The preferential removal of low-angular momentum gas from spiral galaxies through supernova feedback promises to be an effective method for lowering the central concentration in simulated galaxies and producing smaller, more realistic bulges. We study how the removal of low angular momentum gas by supernovae in simulations is affected by the structure of the interstellar media (ISM). Using high-resolution Smoothed Particle Hydrodynamic simulations with efficient supernova feedback in a fully cosmological Lambda CDM context, we followed the evolution of two field galaxies with a maximum velocity of ~120 km/s to a redshift of zero. We analyzed the final structure of these galaxies when simulated with three different models of the ISM: primordial (H+He) cooling down to 10^4 K, additional cooling via metal lines and to lower temperatures, and cooling including both metal lines and shielded molecular hydrogen (H2). We compared the bulge magnitudes and sizes of the simulated galaxies to observed galaxies and found that galaxies simulated either with just primordial cooling or with H2 and metal line cooling in addition to primordial cooling produce realistic bulges. Similarly, these two ISM models produce galaxies with non-centrally peaked rotation curves. For the simulation with just primordial cooling, supernova feedback is more efficient at removing low-angular momentum material because of its artificially high temperature floor. For the simulations with H2, the greater loss of low angular momentum material by supernova feedback is caused by the greater clumpiness of the ISM resulting from the lower temperature floor. The addition of H2, therefore, produces simulations with both more realistic ISMs and more realistic bulges.

323.06 – **Feeding Galaxies: Cold Accretion Through Warps**

David J. Radburn-Smith[1], R. Roskar[2], R. de Jong[3], V. Debattista[4], J. Dalcanton[1]

[1]*University of Washington,* [2]*University of Zurich, Switzerland,* [3]*AIP, Germany,* [4]*University of Central Lancashire, United Kingdom.*

3:10 PM - 3:20 PM

Fueling the high star-formation rates observed in local galaxies remains a key issue of Lambda-CDM. Recent modeling suggests that the fueling gas may stream in through

cold accretion flows. Because these flows may be misaligned with the galaxy disk, they should result in a warped disk. However, cold-flow accretions are not the only possible mechanism for creating warps. Other possible explanations include gravitational torques or gas-rich satellite mergers.

Using new HST observations of the resolved stellar populations in a disk warp, we constrain several of these models. Our best match is to a new simulation of cold-gas infall through a mildly rotating hot gaseous halo. These observations will thus help reveal the role of both hot and cold gas in fueling and forming galaxy disks.

323.07 – **The Detailed Chemical History of M31**

Janet E. Colucci[1], R. A. Bernstein[1]

[1]*University of California, Santa Cruz.*

3:20 PM - 3:30 PM

We present chemical abundances and ages of stellar populations in M31, the nearest massive spiral galaxy. We have measured detailed chemical abundances for over 20 elements in a sample of ~30 M31 globular clusters using high resolution spectra of their integrated light. The GCs are dispersed throughout the inner and outer halo, with galactocentric radii between 2.5 kpc and 117 kpc. We find a range of [Fe/H] within 20 kpc of the center of M31, and a constant [Fe/H]~-1.6 for the outer halo GCs. We also derive cluster ages using Fe lines and present the first accurate age-metallicity relationship for the M31 GC system, with the result that the more metal-rich clusters in the sample are also the youngest. We find consistently high α-element abundances for a large range in [Fe/H] of -2.2 to -0.26. This implies that these M31 GCs formed in an environment with a high star formation rate, perhaps higher and more sustained than the early star formation rate of the Milky Way. We also measure the first abundances of 8 heavy neutron-capture elements, which are the first abundances of their kind in old stellar populations found more than 150 kpc from the Milky Way. These results provide the most comprehensive abundance history ever obtained for any other massive galaxy besides the Milky Way.

324 – Cosmology and Galaxy Formation From SDSS-III/BOSS

Special Session – Room 18C – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

The SDSS-III's Baryon Oscillation Spectroscopic Survey (BOSS) is a 6-year effort to map the spatial distribution of luminous galaxies and quasars and probe the inter-galactic medium. The goals of the survey are to constrain the characteristic scale imprinted by baryon acoustic oscillations in the early universe, the growth of structure through redshift space distortions, the matter power spectrum and the evolution of massive galaxies and quasars. By January 2012 BOSS will have completed its third year of observations and have numerous scientific results to share with the community.
BOSS will continue the SDSS tradition of public data releases. This session will be highlighting results using the first 750,000 spectra, to be released in Summer 2012.

324.01 – **Cosmology with Large Scale Structure**

Shirley Ho[1], A. Cuesta[2], A. Ross[3], H. Seo[4], R. DePutter[5], N. Padmanabhan[2], M. White[4], A. Myers[6], J. Bovy[7], M. Blanton[8], C. Hernandez[9], O. Mena[10], W. Percival[3], F. Prada[11], N. P. Ross[12], S. Saito[13], D. Schneider[14], R. Skibba[15], K. Smith[16], A. Slosar[17], M. Strauss[16], L. Verde[18], D. Weinberg[19], N. Bachall[16], J. Brinkmann[20], L. A. da Costa[21]

[1]*Lawrence Berkeley Lab/ Carnegie Mellon University,* [2]*Yale University,* [3]*University of Portsmouth, United Kingdom,* [4]*University of California, Berkeley,* [5]*University of Valencia/Institut De Ciencies D L'espai, Spain,* [6]*University of Wyoming,* [7]*Institute of Advanced Studies,* [8]*New York University,* [9]*Centro de Estudios de Fsica del Cosmos de Aragn, Spain,* [10]*Instituto De Fisca Corpuscular, University of Valencia, Spain,* [11]*Instituto de Astrofsica de Andaluca, Spain,* [12]*Lawrence Berkeley Lab,* [13]*University of California Berkeley,* [14]*Penn State University,* [15]*University of Arizona,* [16]*Princeton University,* [17]*Brookhaven National Laboratory,* [18]*Institut De Cincies de L'espai, Spain,* [19]*Ohio State University,* [20]*Apache Point Observatory,* [21]*Laboratorio Interinstitucional de e-Astronomia, Brazil.*

2:00 PM - 2:13 PM

The Sloan Digital Sky Survey I-III surveyed 14,000 square degrees, and delivered over a trillion pixels of imaging data. I present cosmological results from this unprecedented data set which contains over a million galaxies distributed between redshift of 0.45 to 0.70.

With such a large volume of data set, high precision cosmological constraints can be obtained given a careful control and understanding of observational systematics. I present a novel treatment of observational systematics and its application to the clustering signals from the data set. I will present cosmological constraints on dark components of the Universe and tightest constraints of the non-gaussianity of early Universe to date utilizing Large Scale Structure.

324.02 – **The 3D Clustering of BOSS DR9 Galaxies**

Ashley Jacob Ross[1], W. J. Percival[1], A. A. Berlind[2], M. Blanton[3], A. Bolton[4], J. Brinkmann[5], L. A. da Costa[6], R. Crittenden[1], A. J. Cuesta[7], D. Eisenstein[8], H. Guo[9], J. Hamilton[10], C. Hernandez-Monteagudo[11], S. Ho[12], E. Kazin[3], C. McBride[8], M. A. Maia[6], R. Mandelbaum[13], M. Manera[1], C. Maraston[1], K. L. Masters[1], F. Montesano[14], A. D. Myers[15], R. C. Nichol[1], N. Padmanbhan[7], J. Parejko[7], F. Prada[16], B. Ramos[6], N. P. Ross[12], I. Zehavi[9], L. Samushia[1], A. Sanchez[14], E. F. Schlafly[8], D. J. Schlegel[12], D. P. Schneider[17], H. Seo[12], F. de Simoni[6], R. Skibba[18], M. Swanson[8], D. Thomas[1], J. Tinker[3], R. Tojeiro[1], M. Vargas[10], D. Wake[7], B. A. Weaver[3], M. White[12], K. Dawson[4]

[1]*University of Portsmouth, United Kingdom,* [2]*Vanderbilt University,* [3]*New York University,* [4]*University of Utah,* [5]*Apache Point Observatory,* [6]*Observatorio Nacional, Brazil,* [7]*Yale University,* [8]*Harvard University,* [9]*Case Western Reserve University,* [10]*Universite Paris-Diderot, France,* [11]*Centro de Estudios de Fisica del Cosmos de Aragon, Spain,* [12]*Lawrence Berkeley National Laboratory,* [13]*Princeton University,* [14]*Max Planck-Institut fur Astrophysik, Germany,* [15]*University of Wyoming,* [16]*Instituto de Astrofisica de Andalucia, Spain,* [17]*Pennsylvania State University,* [18]*University of Arizona.*

2:15 PM - 2:28 PM

The Baryon Oscillation Spectroscopic Survey provides the largest 3D map of the Universe ever obtained. We present results from the DR9 data set, which includes 360,000 galaxies distributed over 3200 square degrees. At large physical scales, these data allow measurements of unprecedented precision in the 3D redshift-space correlation function and the spherically-averaged power-spectrum. In order to utilize this map to measure galaxy clustering, we need to fully understand potential sources of systematic fluctuations in galaxy density, caused by observational effects rather than cosmological fluctuations. I will present a careful analysis of these fluctuations, showing how we can robustly recover the cosmological clustering signal. The measurements and their cosmological interpretation will be presented.

324.03 – **Dense Sampling and Large Volume: The Structure of the Intergalactic Medium from 50,000 SDSS3 BOSS Quasar Absorption Spectra**

Rupert A. Croft[1], E. Arnau[2], E. Aubourg[3], S. Bailey[4], J. Bechtold[5], V. Bhardwaj[6], A. Bolton[7], A. Borde[8], J. Brinkmann[9], N. Busca[10], W. Carithers[4], R. Cen[11], R. Charlassier[12], M. Cortes[4], A. Dall'Aglio[13], S. Cristiani[14], K. Dawson[7], T. Delubac[15], A. Font-Ribera[16], J. Hamilton[17], S. Ho[1], K. Lee[11], J. LeGoff[18], D. Kirkby[19], B. Lundgren[20], B. Menard[21], J. Miralda-Escude[22], N. Palanque-Delabrouille[23], A. Myers[24], I. Paris[25], S. Peirani[25], P. Petitjean[25], M. Pieri[26], J. Rich[18], E. Rollinde[25], N. Ross[4], D. Schlegel[4], R. Skibba[5], A. Slosar[27], N. Suzuki[4], H. Trac[1], S. Vikas[28], M. Viel[14], D. Wake[20], D. Weinberg[26], M. White[29], C. Yeche[18]

[1]*Carnegie Mellon University,* [2]*Barcelona, Spain,* [3]*Paris Diderot, France,* [4]*Lawrence Berkeley Lab,* [5]*University of Arizona,* [6]*University of Washington,* [7]*University of Utah,* [8]*Univ. Paris 13, France,* [9]*Apache Point Observatory,* [10]*APC, France,* [11]*Princeton University,* [12]*DSM/IRFU/SPP (CEA), France,* [13]*AIP Potsdam, Germany,* [14]*Trieste Observatory, Italy,* [15]*CEA, Paris, France,* [16]*IEEC, Spain,* [17]*APC - Paris, France,* [18]*CEA Saclay, France,* [19]*University of California Irvine,* [20]*Yale University,* [21]*Johns Hopkins University,* [22]*University of Barcelona, Spain,* [23]*CEA, Saclay, France,* [24]*University of Wyoming,* [25]*IAP, Paris, France,* [26]*Ohio State University,* [27]*Brookhaven National Lab,* [28]*University of Pittsburgh,* [29]*University of California, Berkeley.*

2:30 PM - 2:43 PM

The BOSS quasar spectra analyzed so far contain over a quarter billion pixels of

information on the intervening intergalactic medium. The statistical power of BOSS has previously enabled 10% of the eventual full dataset to yield the first measurements of three dimensional large-scale structure in the Lya forest (Slosar et al 2011). Here we present results from a sample several times larger, covering several topics in cosmology and intergalactic medium science which are qualitatively transformed by the dense sampling (20 quasars per square degree) and enormous sky area. These include new constraints on cosmology and the neutrino mass from a Lya forest power spectrum measurement using 20 times more spectra than the largest previously published analysis (from SDSS), a new catalog of metal absorbers and a stacking analysis which has uncovered many metal species never before seen in the intergalactic medium. Cross-correlations of quasars, galaxies, metal lines and Lyman series absorption provide us with a wide variety of probes, including of cosmology, quasar host masses, lifetimes, and absorber galaxy masses. We show several of these results. We also show through correlation function analysis that the prime task, of making a BAO detection from Lya forest clustering, (the first BAO constraint between z=1 and the CMB) is well on the way to completion.

324.04 – **Clustering Near the Epoch of Peak Quasar Activity with SDSS-III/BOSS**

Adam D. Myers[1], E. Aubourg[2], S. Bailey[3], J. Bovy[4], X. Fan[5], S. Ho[6], L. Jiang[5], J. Miralda-Escude[7], N. Palanque-Delabrouille[2], P. Petitjean[8], N. Ross[3], D. Schlegel[3], D. Schneider[9], M. Strauss[10], D. Weinberg[11], M. White[12], C. Yeche[2], I. Zehavi[13]
[1]University of Wyoming, [2]CEA Saclay, France, [3]Lawrence Berkeley National Laboratory, [4]The Institute for Advanced Study, [5]Steward Observatory, [6]Carnegie Mellon University, [7]Universitat de Barcelona, Spain, [8]Universite Paris, France, [9]The Pennsylvania State University, [10]Princeton University, [11]The Ohio State University, [12]UC Berkeley, [13]Case Western Reserve University.
2:45 PM - 2:57 PM

The Sloan Digital Sky Survey has revolutionized our understanding of quasar clustering at high redshift. But, above redshift 2.5, SDSS-I and II mainly took spectra of quasars at the bright end of the luminosity function. The clustering of fainter quasars above redshift 2.5 can break degeneracies between quasar fueling and host galaxy mass, newly constraining the length of the quasar phase near the peak of quasar activity. The SDSS-III/BOSS survey is compiling a sample of around 150,000 quasars above redshift 2.2, around half of which are above redshift 2.5. By design, a core subsample of BOSS quasars have a well-controlled angular selection function that facilitates clustering measurements. I will present measurements of quasar clustering from the first 2 years of BOSS, focusing on redshifts around $2.2 < z < 2.7$. As statistics develop over the full 5-year survey, BOSS will measure the clustering of low-luminosity quasars at $2.5 < z < 3.5$ with unprecedented precision.

324.05 – **Spectroscopic Properties and Chemical Evolution of BOSS Galaxies**

Daniel Thomas[1], O. Steele[1], C. Maraston[1], J. Johansson[1], A. Beifiori[1], J. Pforr[1], G. Stroembaeck[1], C. Tremonti[2], D. Wake[3], R. Yan[4]
[1]University of Portsmouth, United Kingdom, [2]University of Wisconsin-Madison, [3]Yale University, [4]New York University.
3:00 PM - 3:13 PM

SDSS-III/BOSS will take spectra of about 1.5 million massive galaxies up to redshift 0.7, providing a rich data set for galaxy evolution studies. In this talk I present the results from the spectroscopic analysis of ~500, 000 galaxy spectra from the first two years of observations. We show that the typical signal-to-noise ratio of BOSS spectra is sufficient to make measurements of stellar velocity dispersion and emission line fluxes. The typical velocity dispersion of a BOSS galaxy is 250 km/s independent of redshift, which reflects the survey design targeting massive galaxies with a uniform mass distribution at all redshifts. As expected, the majority of BOSS galaxies are emission line free, and the fraction of galaxies with a significant detection of weak emission lines is small (about 5 per cent). We show that galaxies at $z > 0.4$ whose emission lines are produced by star formation activity have blue observed g-r colours and are well separated in the target selection colour-colour space. From stacked spectra we derive chemical element abundance ratios of BOSS galaxies up to z~0.7 through the comparison of measured absorption line indices with stellar population model predictions, and discuss their evolution with redshift. The Science, Technology and Facilities Council (UK) is acknowledged for support.

324.06 – **Overview of New Results from the Stripe 82 Equatorial Field**

Alexie Leauthaud[1], M. White[2], D. Schlegel[1], J. Kneib[3], L. van Waerbeke[4], M. Makler[5], N. P. Ross[1], SDSS-III/BOSS collaboration, CS82 collaboration
[1]LBNL, [2]Berkeley, [3]LAM, France, [4]UBC, Canada, [5]ICRA/CBPF - LIneA, Brazil.
3:15 PM - 3:30 PM

Stripe 82 is emerging as one of the new premier survey fields with an area of over 100 deg^2 and an impressive array of multi-wavelength observations already in hand or in progress (e.g., SDSS ugriz imaging, BOSS spectroscopy of >40,000 galaxies and QSOs, GALEX UV imaging, 1.4 and 3 GHz radio coverage, CFHT i<23.7, J and K imaging from CFHT and VISTA). First, I will give an overview of these data sets, including several new Stripe 82 surveys such as the "CFHT Stripe 82 Survey": a new 170 deg^2 CFHT i-band survey that has been analysed with the state-of-the-art weak lensing quality data processing and shear measurement pipeline from CFHTLenS. Next, I will highlight some new results from Stripe 82 including BOSS galaxy mass functions to z=0.7, weak lensing, new cluster catalogs to z=0.7, and the luminosity dependance of QSO clustering.

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325 – Careers in Media for Scientists

Special Session – Ballroom G – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

A panel of experienced science journalists will discuss careers in the media that accommodate persons trained in Astronomy or other sciences up to the Ph.D.
David Aguilar, Harvard-Smithsonian Center for Astrophysics
Deborah Byrd, EarthSky: A Clear Voice for Science
Richard T. Fienberg, American Astronomical Society
James Glanz, The New York Times
Laura Helmuth, Smithsonian Magazine

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326 – Extrasolar Planets I

Oral Session – Ballroom F – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

326.01 – **Ground-based Infrared Spectroscopy of the Extremely Hot Jupiter WASP-12b**

Ian J. M. Crossfield[1], B. Hansen[1], T. Barman[2]
[1]UC Los Angeles, [2]Lowell Observatory.
2:00 PM - 2:10 PM

Photometric characterization of transiting extrasolar planets leaves substantial degeneracies in atmospheric composition and structure, but properly calibrated spectroscopy can resolve these uncertainties and provide tighter constraints on atmospheric structure and abundances. Our team is observing transits and eclipses in the near-infrared to obtain spectra of a subset of transiting planets. I will present our tentative detection of the thermal emission spectrum of Hot Jupiter WASP-12b. We seem to confirm the 3,000 K near-infrared brightness temperature but our results are not precise enough to constrain individual molecular features. I will also present results from four transits of the low-mass planet GJ 1214b, which has been claimed to host a cloud-covered or non-H-dominated atmosphere.

326.02 – **Near-infrared Thermal Emission of hot Jupiters**

Bryce Croll[1]
[1]M.I.T..
2:10 PM - 2:20 PM

I will present results from our ongoing program using the Wide-field Infrared Camera (WIRCam) on the Canada-France-Hawaii Telescope (CFHT) to detect thermal emission from hot Jupiters in the near-infrared. I'll present an in depth analysis of the highly irradiated hot Jupiter WASP-12b, by presenting reobservations of its secondary eclipse in the JHK-bands, as well as the first thermal emission measurement of a hot Jupiter in Y-band (~1.04 microns). I'll also explore what the plethora of detections of the thermal emission of these planets in the near-infrared contributes to our understanding of the atmospheric characteristics of hot Jupiters as a class.

326.03 – **Planet-Disk Interactions on a Moving Mesh**

Diego Munoz[1]
[1]Harvard University.
2:20 PM - 2:30 PM

We present a novel approach to the numerical study of gas disks around young stars using the Voronoi-tessellation cosmological code AREPO (Springel,2010).

This finite-volume code is shock-capturing and second-order-accurate in time and space. Its moving mesh makes it a Lagrangian/Eulerian code that satisfies Galilean invariance and has a very low diffusivity due to its unbiased unstructured grid. Its pseudo-Lagrangian nature makes it ideal for problems that show large dynamical range in density, such as gravitationally unstable systems with clustering and collapse. The self-gravity solver is implemented consistently for collisionless particles as well as for gas ``particles" (Voronoi cells) in an N-body fashion using a tree algorithm.

The hydrodynamics+N-body approach of AREPO is unparalleled in its ability to treat self-gravitating systems that lack of a symmetric configuration while retaining the resolution and accuracy of conventional grid codes. Thus, it combines the benefits of both particle- and mesh-based codes. Precisely, these two approaches are used in numerical studies of circumstellar disks depending on the physical process of interest. For example, those studies that choose particle based codes -- such as SPH -- focus on gravitationally unstable disks or the tidal interaction of disks. On the other hand, grid codes are preferred in studies of planet-disk interaction, where proper treatment of shocks, wakes and gaps requires an accurate shock-capturing method. We present examples of how the flexible approach of AREPO can be used to simulate these and other types of problems, with a particular focus on planet-disk interaction, disks with gaps and planet migration in self-gravitating disks.

326.04 – **Planet Distribution Evolution Towards Destruction By Roche Lobe Overflow**

Stuart F. Taylor[1]

[1]*National Tsing Hua University, Taiwan.*

2:30 PM - 2:40 PM

We explore the tidal migration of the hot Jupiter distribution found from Kepler data to show that the three day pile up is consistent with a higher rate of in-migration for the most massive planets (Figure 1). The manner in which the distribution of the most massive planets turns over closer to the star may be due to a population of eccentric planets being rapidly migrated towards the star by processes such as planet scattering and Kozai migration.

We show that planets undergoing Roche lobe overflow may last a very long time (Figure 2). Such events may last longer than the 50,000 years which Spezzi et al. [1] suggest explains objects they found that appear as overlu-minous bright brown dwarf-like objects. S11 found nine objects with temperatures more typical of brown dwarfs (BDs) in the massive galactic cluster NGC 3603 but with luminosities much too high. They conclude that planets filling their Roche lobe provide the best explanation for these objects. We also show that planets more massive than Jupiter may observably increase the luminosity of the star, but Jupiter-mass planet might not. We show that a broad range of planet masses will migrate outwards during their overflow mass loss, but once a more dense core starts to overflow, the planet will migrate back in.

We hypothesize that the three day pile-up may represent a “pause” in the migration of planets, rather than a stopping point. We report on characterizing the planet distribution to include a pileup. We report on the evolution of planet distributions depending on the value of the tidal friction.

326.05D – **Hot Jupiter Upper Atmospheres: Model Transit Signals in Lyman-alpha for HD 209458b**

George B. Trammell[1], P. Arras[1], Z. Li[1]

[1]*University of Virginia.*

2:40 PM - 3:00 PM

Gas giant exoplanets in tight orbits about their parent stars ("hot Jupiters") are in extreme environments not experienced by any solar system planet. Hot Jupiter upper atmospheres are intensely heated and some are observed to nearly fill their Roche Lobe, leading to suggestions that these planets are losing mass in an outflow.

However, the high ionization levels expected in the upper atmosphere imply that any outflow would be well-coupled to the planetary magnetic field, which may play a non-negligible role in the gas dynamics. We have constructed the first models of the upper atmosphere that include the effects of the intrinsic planetary magnetic field, as well as the stellar tide. The solutions exhibit the following three features: (1) a region near the equator of static, magnetically-confined gas, (2) a transonic outflow at mid-latitudes in a magnetically-channeled wind zone, and (3) a region near the poles where outflow can be quenched by a sufficiently strong stellar tide.

This MHD wind model provides a self-consistent calculation of the density/velocity structure of the upper atmosphere and mass/angular momentum loss rates, which are not well constrained by observations. Lyman-alpha transmission spectra computed from simulations and comparisons with the observed data have provided constraints on the atmospheric structure. One qualitative result of our work is that the observed Lyman-alpha absorption at several planetary radii may not directly constrain the mass loss rate, since the absorption is mainly due to gas confined in the planet's magnetosphere, rather than gas participating in an outflow.

326.06 – **Tidal Venuses: Triggering a Climate Catastrophe via Tidal Heating**

Rory Barnes[1], K. Mullins[1], C. Goldblatt[2], V. S. Meadows[1], J. F. Kasting[3]

[1]*University of Washington,* [2]*University of Victoria, Canada,* [3]*Pennsylvania State University.*

3:00 PM - 3:10 PM

The inner edge of the habitable zone is often defined by the tightest orbit which does not trigger a moist or runaway greenhouse. Previously it was believed that only stellar radiation could trigger these phenomena for a long enough duration to dessicate a planet and preclude habitability. We show that for some planets orbiting low-mass main sequence stars (<0.3 solar masses), brown dwarfs and white dwarfs, tidal heating can reach levels that initiate a runaway greenhouse. We call these planets "Tidal Venuses." As tides circularize the orbit and drive the obliquity to 0 or π, the heating level drops, but tidal heating can persist long enough to remove all of a planet's water. Therefore a planet may be discovered in the habitable zone with very low eccentricity (and hence without enough tidal heat to drive a runaway greenhouse), and yet be uninhabitable due to a previous epoch of extreme tidal heating. In multi-planet systems, interactions with other companions may maintain non-zero eccentricities and obliquities, increasing the threat of catastrophic tidal heating. As terrestrial planets are discovered around low luminosity primaries, careful consideration of current and past tidal heating will be essential for estimating a planet's likelihood to be inhabited, and hence in allocating resources for its characterization.

326.07 – **Uniform Modeling of the Kepler Objects of Interest Catalog.**

Jason Rowe[1], E. V. Quintana[1], T. S. Barclay[2], S. T. Bryson[3], J. L. Christiansen[1], F. R. Mullally[1], S. E. Thompson[1], Kepler Team

[1]*NASA Ames/SETI Institute,* [2]*NASA Ames,* [3]*NASA Ames Research Center.*

3:10 PM - 3:20 PM

We present the first catalog of uniform state-of-the-art lightcurve modeling for Kepler's list of planetary candidates using tested and validated algorithms. This process involved modeling planetary transits, phase curves and orbits. We used observables obtained from Kepler-photometry and groundbased follow-up to determine key planetary parameters such as the radius and mass. More importantly, we determined posterior probability distributions for the fitted parameters by employing a Markov chain Monte Carlo algorithm.

We have measured with uncertainties: stellar parameters, orbital periods, planet radii, inclinations. When sufficient groundbased radial velocities are available we have modeled orbital solutions and planetary densities. We also model multi-planet, transiting systems by fitting for each planet-candidate simultaneously.

326.08 – **Direct Detection of Exoplanets with Polarimetry**

Sloane Wiktorowicz[1], G. Laughlin[1]

[1]*University of California, Santa Cruz.*

3:20 PM - 3:30 PM

The detection of scattered light from exoplanets gives direct access to structure and composition of their atmospheres. Currently, most scattered light experiments focus on nearly edge-on, transiting systems. The temporal changes that occur during planetary occultations are used to suppress systematic errors that would otherwise overwhelm the planetary signal. However, linear polarimetry also has the potential to detect scattered light from exoplanets. This is because the polarization state of light scattered by a planetary atmosphere distinguishes it from both the direct light from the host star and the Wien tail of thermal re-radiation from the planet. Scattered flux should be identifiable even in face-on systems, because both degree and position angle of polarization are modulated continuously throughout the orbit. Orbital inclination, mean number of scattering events, and scattering particle size and index of refraction are potentially discernable with polarimetry. We will report on the search for scattered light from known exoplanets using the POLISH2 polarimeter on the Lick 3-m telescope. This instrument simultaneously measures all four Stokes parameters (I, Q, U, and V), and it achieves precision within 60% of the photon shot noise limit over an entire observing run. The POLISH2 polarimeter is therefore ideally suited for direct detection of close-in exoplanets. This work is supported by a UC Lab Fees Research Grant, UCO/Lick Observatory, and a NExScI Sagan Fellowship.

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327 – Very Young Stars and Accretion Disks

Oral Session – Ballroom E – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

327.01 – **Outflows from Thick, Turbulent Accretion in High Accretion-Rate Protostellar Systems**

Peter T. Williams[1]

[1]*Agilent Technologies.*

2:00 PM - 2:10 PM

In previous work we argued that jets might not be produced through magnetocentrifugal acceleration, but rather through the toroidal stresses of magnetorotational instability (MRI)-driven turbulent magnetohydrodynamic (MHD) accretion in a geometrically thick disk or flow. High accretion-rate protostars are among the best candidates for this process because a geometrically thick accretion disk that extends down to the central star is more plausible in this context than in other protostellar systems. These systems are also cleaner objects to study than active galactic nuclei (AGN), microquasars, and the like, which necessarily involve more exotic relativistic physics.

Here we present a novel in-depth analysis of the laboratory analog that inspired our work on this topic. This analog consists of the meridional flow around a rotating sphere in a viscoelastic fluid. We examine in detail the fluxes of mass, angular momentum, linear momentum, and energy, and how these depend upon system parameters. We find that the presence of an axial outflow depends critically upon the ratio of the analogous turbulent magnetic stress to turbulent Reynolds stress, which must be roughly equal to or larger than unity to drive an outflow. We also find that the flux of angular momentum can actually be opposed to the flow of matter within the outflow, despite the fact that the outflow is ultimately powered by the radial transport of angular momentum from the central object. In particular we show that, in contrast with magnetocentrifugal acceleration, the angular momentum of the outflow actually decreases even while the material is being axially accelerated. This translates to observational tests in protostellar jets.

There are some obvious enormous differences between compressible flow in a gravitational field and incompressible flow in a laboratory. We address this and we and argue why, despite these differences, there is much to learn from this laboratory system.

327.02 – **X-raying A Cold, Dark Dragon To Find A Hot, Glowing Heart**

Matthew S. Povich[1], L. K. Townsley[1], W. Orbin[1]

[1]*Penn State University.*

2:10 PM - 2:20 PM

We present first results from a 100-ks Chandra X-ray observation of the M17 SWex giant molecular cloud. M17 SWex is an infrared dark cloud (IRDC) resembling a flying dragon in Spitzer Space Telescope images. This IRDC is a very young but very active region of star formation, containing ~200 intermediate-mass (2-8 Msun) young stellar objects (YSOs) plus a few massive YSOs and ultracompact H II regions. Our Chandra/ACIS image detected >850 X-ray point sources, spatially clustered along the IRDC filaments and many associated with embedded, intermediate-mass YSOs. This abundance of X-ray sources far exceeded expectations, given the extreme youth and high extinction ($A_V > 30$ mag) of the region. Our preliminary results suggest that (1) M17 SWex is an even more active star-forming region than supposed, and/or (2) young, intermediate-mass, pre-main-sequence stars have surprisingly high X-ray luminosities. We have also found indications of diffuse, soft X-ray emission associated with the IRDC. The origins of this diffuse emission are mysterious.

M.S.P. is supported by an NSF Astronomy and Astrophysics Postdoctoral Fellowship under award AST-0901646.

327.03D – **Emission from Hot Gas in Pre-Main Sequence Objects: The Accretion Shock and the Inner Disk**

Laura Ingleby[1]

[1]*University of Michigan.*

2:20 PM - 2:40 PM

Gas in the inner circumstellar disk may be essential for circularizing the orbits of terrestrial planets, but disk gas is difficult to observe so its evolution is not well characterized. Intricately related to the gas evolution is the evolution of the accretion of inner disk gas onto the central star. High energy emission produced in an accretion shock at the stellar surface irradiates and heats the inner disk. I show that the properties of disk gas, in turn, affect the rate of accretion. Observations of H2 show that the depletion of gas in the inner disk eventually turns off accretion. These final stages of the gas have important implications for theories of disk dissipation, in particular photoevaporation by radiation from the central star. Recent models suggest that mass loss rates by photoevaporation may reach 10^{-8} solar masses per year, comparable to measured accretion rates for T Tauri stars. I will discuss one source which has an evolved disk, based on its infrared spectral energy distribution, yet does not exhibit the signatures of photoevaporation which are traced by dust emission (e.g. a gap or hole in the disk). With an upper limit on the accretion rate of 3×10^{-10} solar masses per year, regions of dust in the disk should be cleared, yet this is not observed. Clearly photoevaporation at such high rates is not feasible in this case. Finally, I discuss the evolution of high energy X-ray and far-ultraviolet emission, which drive photoevaporation, from the star and the accretion shock. I show that X-ray emission is consistently high throughout the disk lifetime, yet the far-ultraviolet emission decreases on timescales consistent with the end of accretion. These observations constrain photoevaporation models by providing the radiation field present and an upper limit on the mass loss rate via the mass accretion rate.

327.04D – **The Tail-end of Primordial Disk Depletion - a Multiwavelength Gas and Dust Survey in Upper Scorpius**

Geoffrey Mathews[1]

[1]*University of Hawaii.*

2:40 PM - 3:00 PM

To improve our understanding of circumstellar disk evolution, and hence constraints on planet formation, I have carried out a survey for gas and dust emission around stars in the 5 Myr Upper Scorpius group. Using deep millimeter photometry from the IRAM 30m telescope, I have found the dust mass distribution of these stars; only 4% of Upper Scorpius K and M stars have millimeter dust masses of 4×10^{-3} Jupiter masses or greater, and no B or A stars retain dust above debris levels. Using JCMT CO observations and atomic gas line observations with the Herschel Space Observatory (as part of the Gas in Protoplanetary Systems key project), I have found an even lower fraction of disks bear detectable gas. I also present millimeter interferometry of the sole known transition disk in Upper Scorpius, with a discussion of its potential depletion mechanisms. By comparison to the large fraction of Kepler targets with Neptune size planets, these findings suggest that the process of giant planet formation must be well advanced in Upper Scorpius.

327.05 – **The Star-formation History and Accretion Disk Fraction Among the Low-Mass Members of the Scorpius-Centaurus OB Association**

Mark Pecaut[1], E. E. Mamajek[1]

[1]*University of Rochester.*

3:00 PM - 3:10 PM

As part of a long-term observing program to elucidate the membership, star-formation history, and substructure of the nearest OB association (Sco-Cen; d = 100-150 pc; ages 10-20 Myr), we present results from a low-resolution optical spectroscopy survey of 363 G/K/M-type candidates of Sco-Cen selected via X-ray activity, proper-motions, and 2MASS photometry consistent with membership. Using low-resolution spectra over red (~5700A-6800A) wavelengths obtained using the SMARTS 1.5-m telescope, we measured Li equivalent widths, determined accurate MK spectral classifications and searched for evidence of accretion among these low-mass stars (~0.6-1.1 Msun). Using Li as a youth indicator, we evaluate membership and place each confirmed member on the H-R diagram. Combining these results with previously published results for the higher- and lower-mass stars, we discuss the substructure, age distribution, and kinematics of the Sco-Cen OB association, as well as the accretion disk fraction amongst young G/K/M-type stars in the 10-20 Myr range. This work has been supported by NSF grant AST-1008908.

327.06D – **Protostellar Luminosity Functions in 11 Diverse Star Forming Environments**

Erin Kryukova[1], S. T. Megeath[1], R. Gutermuth[2], J. Pipher[3], T. S. Allen[1], L. E. Allen[4], P. C. Myers[5], J. Muzerolle[6], Cygnus-X Legacy Team

[1]*University of Toledo,* [2]*FCAD/Smith College, University of Massachusettes,* [3]*University of Rochester,* [4]*National Optical Astronomy Observatories,* [5]*Harvard-Smithsonian Center for Astrophysics,* [6]*Space Telescope Science Institute.*

3:10 PM - 3:30 PM

Protostars exist in a variety of environments, ranging from clouds with dispersed low-mass stars, such as Taurus, to clustered regions in clouds forming high-mass stars, like Orion. The effect these different environments have on protostar properties such as mass or luminosity is uncertain. One way to probe the effects of cloud environment on the observable property, protostar luminosity is to compare protostellar luminosity functions of clouds hosting varied populations of protostars. In this dissertation talk I will discuss the protostellar luminosity functions from 11 star forming clouds including Lupus, Chamaeleon, Ophiuchus, Perseus, Serpens, Orion, Cep OB3, Mon R2, Cygnus-X, and Maddalena's Cloud, which encompass a wide range of star forming environments. The luminosity functions are constructed from Spitzer surveys of these molecular clouds. I employ a new technique for estimating the bolometric luminosity from near and mid-IR fluxes alone and for subtracting contamination from galaxies, reddened pre-main sequence stars with disks, and edge-on disk systems. The clouds which are forming massive stars show a significant peak at low luminosity and a tail extending toward luminosities above 10 solar luminosities, while the luminosity functions of clouds which are not forming massive stars have no significant peak down to the sensitivity limit and do not exhibit the tail. I compare these luminosity functions to existing models of protostellar evolution. I also compare the luminosity functions of protostars in distributed and clustered environments, as determined using nearest-neighbor distances. In Orion and Cygnus-X, the clouds which contain the largest populations of protostars there is a clear difference in luminosity functions between protostars incrowded and distributed regions, with the luminosity function biased towards higher luminosities in more luminous regions. I will discuss the implications of these variations and the possibility that the IMF is varying within the star forming regions.

328 – Instrumentation: Space Missions

Oral Session – Room 17B – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

328.01D – **Optimal Electric Field Estimation and Broadband Control for Coronagraphy**

Tyler Dean Groff[1]

[1]*Princeton University.*

2:00 PM - 2:20 PM

Future space-based coronagraphs will require focal plane wavefront control techniques to achieve the necessary contrast levels to achieve an earth-like planet detection. These correction algorithms are iterative and the control methods require an estimate of the electric field at the science camera. The Stroke Minimization algorithm developed at the Princeton High Contrast Imaging Laboratory has proven symmetric dark hole generation using minimal stroke on two deformable mirrors (DM) in series. We extend the concept of minimizing DM actuation to achieve symmetric dark holes in broadband light, thus minimizing the number of exposures required to obtain a spectra. Since it is the estimation step that uses the majority of the images in the correction algorithm, we make the broadband suppression problem more efficient in two ways. The first is to use a model based extrapolation technique so that the broadband suppression algorithm only requires a single monochromatic estimate of the electric field. Second, we reduce the number of exposures in the field by employing state estimate feedback in the form of a Kalman filter. The Kalman filter formalism guarantees that the estimate becomes near-optimal with regard to actuation and sensor noise. Implementation of the Kalman filter also allows for parameter adaptive control, which will increase the robustness of the control algorithm to disturbance. Optimality of the entire problem can also be addressed through the use of a dual controller, allowing the algorithm to perturb or suppress the field in an optimal way so that the final high contrast levels can be achieved with the fewest exposures possible. We present experimental and theoretical progress of these estimation and control problems for high contrast imaging. This work is funded by NASA Grant #NNX09AB96G and the NASA Earth and Space Science Fellowship.

328.02 – **Progress In A New Reflective Coating From The Far-ultraviolet To The Near-infrared.**

Matthew N. Beasley[1], H. Greer[2], S. Nikzad[2]

[1]*University of Colorado at Boulder, CASA,* [2]*Jet Propulsion Laboratory.*

2:20 PM - 2:30 PM

We present new progress in optical coatings (very thin MgF2 over aluminum) that have to the potential to revolutionize far-ultraviolet astronomy by dramatically improving the efficiency. By protecting the aluminum with a layer that does not impact far-ultraviolet performance, we will achieve nearly perfect aluminum reflectivity. Due to the nature of our coating, in addition to unprecedented far-ultraviolet reflectivity the coating will provide truly broadband performance out to much longer wavelengths. We use atomic layer deposition to ensure a protected aluminum surface that minimizes the impact of the protective overcoat. The minimal impact of the overcoat may be important to the induced polarization of the optical surfaces, leading to potentially improved telescopes for exo-planet science, and might allow a combined exo-planet UVOIR mission.

328.03D – **NuSTAR: Unveiling the Hard X-ray Universe**

Varun Bhalerao[1], NuSTAR team

[1]*Caltech.*

2:30 PM - 2:50 PM

The Nuclear Spectroscopic Telescope Array (NuSTAR) mission will carry the first focussing Hard X-ray (6-80 keV) telescope into orbit in Feb 2012. Using grazing incidence optics and pixelated CdZnTe detectors, it will offer two orders of magnitude increase in sensitivity and an order of magnitude improvement in angular resolution over any previous instrument working in this energy range.

The two-year primary science mission focuses on four key programs: studying the cosmic evolution of black holes, understanding the populations of compact objects and the nature of the central black hole in the Milky Way, constraining the explosion dynamics and nucleosynthesis in supernovae, and probing the nature of particle acceleration in active galactic nuclei. A number of additional observations will be included in the primary mission, and a guest observer program will be proposed for an extended mission to expand the range of scientific targets.

I was involved in calibration of the hard X-ray focal plane detectors. I built a setup for fine calibration of the spatial response of the detectors, and translated this into response files for science data analysis. I have also been involved with the science team responsible for planning observations for the two year baseline mission.

328.04 – **The Advanced X-ray Spectroscopic Imaging Observatory**

Jay A. Bookbinder[1], R. Smith[1], M. Garcia[1], H. Tananbaum[1], N. White[2], R. Petre[2], A. Ptak[2], A. Hornschemeier[2], W. Zhang[2], S. Bandler[2], G. Daelemans[2], M. Bautz[3], R. Hielmann[3], R. McEntaffer[4], J. Bregman[5], P. Reid[1]

[1]*Smithsonian Astrophysical Obs.,* [2]*NASA/GSFC,* [3]*MIT,* [4]*University of Iowa,* [5]*University of Michigan.*

2:50 PM - 3:00 PM

The Advanced X-ray Spectroscopic Imaging Observatory (AXSIO) is a NASA facility class X-ray observatory which can carry out many of the science goals of the International X-ray Observatory as outlined in the NWNH Astro2010 Decadal Survey. Studies of the mission configuration and science reach will inform NASA technology investments over the next several years. The primary science goals will be directly observing the effects of strong gravity in black holes; mapping temperatures, abundances and dynamics in hot gas on scales ranging from the local ISM to galaxy clusters; observing feedback from AGN and star formation in galaxies; finding the missing baryonic matter; and studying the structure of neutron stars.

The mission configuration required to achieve these goals builds on the IXO segmented glass optics technology, but with a (shorter)10m focal length. These optics provide 10 arcsec HPD (5 arcsec goal) images and ~1m^2 of area at 1.25keV and ~0.2m^2 at 6keV. A new micro-calorimeter configuration provides 2 eV spectral resolution over a central 0.6 arcmin area, and < 5eV over a 4.8 arcmin square extended region. A grating spectrometer provides the low-energy spectroscopy (from 0.3keV to 1.0keV) with spectral resolution of>3000 and an effective area of>1000cm^2.

328.05 – **The Dark Ages Radio Explorer (DARE): First Stars, First Galaxies, and First Black Holes**

Jack O. Burns[1]

[1]*Univ. of Colorado at Boulder.*

3:00 PM - 3:10 PM

A concept for a new space-based cosmology mission called the Dark Ages Radio Explorer (DARE) will be presented in this talk. DARE's science objectives include (1) When did the first stars form? (2) When did the first accreting black holes form? (3) When did Reionization begin? (4) What surprises does the end of the Dark Ages hold (e.g., Dark Matter decay)? *DARE will use the highly-redshifted hyperfine 21-cm transition from neutral hydrogen to track the formation of the first luminous objects by their impact on the intergalactic medium during the end of the Dark Ages and during Cosmic Dawn (redshifts z=11-35). It* will measure the sky-averaged spin temperature of neutral hydrogen at the unexplored epoch 80-420 million years after the Big Bang, providing the first evidence of the earliest stars and galaxies to illuminate the cosmos and testing our models of galaxy formation. DARE's approach is to measure the expected spectral features in the sky-averaged, redshifted 21-cm signal over a radio bandpass of 40-120 MHz. DARE orbits the Moon for a mission lifetime of 3 years and takes data above the lunar farside, the only location in the inner solar system proven to be free of human-generated radio frequency interference and any significant ionosphere. The science instrument is composed of a low frequency radiometer, including electrically-short, tapered, bi-conical dipole antennas, a receiver, and a digital spectrometer. The smooth frequency response of the antennas and the differential spectral calibration approach using a Markov Chain Monte Carlo technique will be applied to detect the weak cosmic 21-cm signal in the presence of the intense solar system and Galactic foreground emissions.

328.06 – **Reducing the Read Noise of the James Webb Near Infrared Spectrograph by Improved Reference Sampling & Subtraction (IRS-square)**

Bernard J. Rauscher[1], S. H. Moseley[1], R. G. Arendt[1], D. Fixsen[1], D. Lindler[2], M. Loose[3]

[1]*NASA's GSFC,* [2]*Sigma Space, Inc.,* [3]*Markury Scientific.*

3:10 PM - 3:20 PM

In a previous paper, we described a method for significantly reducing the read noise of HAWAII-2RG (H2RG) and SIDECAR application specific integrated circuit (ASIC) based detector systems by making better use of reference signals. "Improved Reference Sampling & Subtraction" (IRS^2; pronounced "IRS-square") is based on: (1) making better use of the H2RG's reference output, (2) sampling reference pixels more frequently in the time domain, and (3) optimal subtraction of both the reference output and reference pixels in the Fourier domain. Here we demonstrate that IRS^2 works as expected using an engineering grade *James Webb Space Telescope* (*JWST*) SIDECAR ASIC and H2RG detector array. We were able to reduce the read noise per frame from 25 e^- rms using traditional *JWST* readout to 10 e^- rms per frame using IRS^2. The only aspect of the system that we changed to make these impressive improvements was the SIDECAR ASIC readout software -we did not change the hardware.

328.07 – **Ultra-Fast Flash Observatory (UFFO) For Early Photon Measurements From Gamma Ray Bursts**

Il Park[1], B. Grossan[2], E. Linder[3], G. F. Smoot[4], UFFO Collaboration

[1]*Ewha W. University, Korea, Republic of,* [2]*UC Berkeley Space Sciences*

Laboratory, [3]Lawrence Berkeley Lab, UC Berkeley, [4]UC Berkeley.
3:20 PM - 3:30 PM

We describe the Ultra-Fast Flash Observatory (UFFO), which will observe early optical photons from gamma-ray bursts (GRBs) with a sub-second optical response, for the first time. The UFFO will probe the early optical rise of GRBs, opening a completely new frontier in GRB and transient studies, using a fast-response MEMS (Micro-Electro-Mechanical Systems) Mirror Array (MMA)-based optical system. In our small UFFO-Pathfinder experiment, scheduled to launch aboard the Lomonosov satellite in April 2012, we use a motorized mirror in our Slewing Mirror Telescope instrument to achieve less than one second optical response after X-ray trigger. We describe the science and the mission of the UFFO-Pathfinder project, as well as our plans of a full-scale UFFO-100 as the next step. With our program of ultra-fast optical response GRB observatories, we aim to gain a deeper understanding of GRB mechanisms, and potentially open up the z>10 universe to study via GRB as point source emission probes.

329 – Galaxy Evolution in the Cluster Environment

Oral Session – Room 16B – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

329.01 – **Assembly of the Red Sequences in Galaxy Clusters**

Gregory F. Snyder[1], M. Brodwin[2], C. M. Mancone[3], G. R. Zeimann[4], S. A. Stanford[4], A. H. Gonzalez[3], D. Stern[5], P. R. H. Eisenhardt[5]

[1]Harvard University, [2]University of Missouri-Kansas City, [3]University of Florida, [4]University of California-Davis, [5]Jet Propulsion Laboratory, California Institute of Technology.
2:00 PM - 2:10 PM

I present results for the assembly and star formation histories of massive red sequence galaxies in over ten spectroscopically-confirmed, infrared-selected galaxy clusters at $1.0 < z < 1.8$, the precursors to present-day massive clusters. Using rest-frame optical photometry, we investigate evolution in the color and scatter of the red sequence galaxy population, comparing with models of possible star formation histories. In contrast to many similar studies at lower redshift, these galaxies are clearly inconsistent with the continued passive evolution of stars formed and assembled at a single, much-earlier time. This sample exhibits a striking range in the inferred formation epochs of cluster red sequences, reflecting either a wide diversity of single-burst formation epochs or the effects of significant progenitor bias owing to ongoing assembly. We discuss the implications of simple manifestations of ongoing stellar assembly on the observed colors, which generally indicate that cluster ellipticals began forming a significant mass of stars at $z > 4$, were identifiable as red spheroids by $z = 1.5$ at the latest, and were actively assembling much of their final mass during $1 < z < 2$ in the form of younger stars.

329.02 – **Post-merger Signatures Of Red-sequence Galaxies In Rich Abell Clusters At Z~0.1**

Yun-Kyeong Sheen[1], S. K. Yi[1], C. H. Ree[2]

[1]Yonsei University, Korea, Republic of, [2]Korea Astronomy and Space Science Institute, Korea, Republic of.
2:10 PM - 2:20 PM

We have investigated post-merger signatures of red-sequence galaxies in rich Abell clusters at z~0.1. u',g',r' deep images and medium-resolution galaxy spectra are taken for A119, A2670, A3330 and A389 with MOSAIC 2 CCD and Hydra MOS mounted on Blanco 4-m telescope at CTIO. Post-merger signatures are identified by visual inspection with their asymmetric features, e.g. tails, rings and discontinuous halo structures. We found that about 30% of bright ($M_r < -19$) red-sequence galaxies show post-merger signatures in four target clusters consistently. This is markedly lower than the value derived in the field (~70% with field ellipticals, van Dokkum 2005). Among the featured galaxies, 20-40% of galaxies indicated traces of residual star formation with their UV deep images, probably induced by galaxy mergers and interactions. We also examined bulge-to-total ratio and asymmetry of the cluster member galaxies. In result, a large fraction of the featured galaxies turned out to be bulge-dominated systems and asymmetry in post-merger galaxies were larger than that of normal early-type galaxies on average. In this presentation, we will discuss implications of the results on the formation of red-sequcne galaxies in cluster environment.

329.03D – **Star and Filament Formation; Signatures of AGN Feedback in Brightest Cluster Galaxies**

Rebecca Canning[1]

[1]University of Cambridge, United Kingdom.
2:20 PM - 2:40 PM

My research has focussed primarily on new, detailed, multi-wavelength studies of three nearby brightest cluster galaxies (BCGs), NGC 4696 in the Centaurus cluster, PKS 1404-267 and NGC 1275 in the Perseus cluster. These systems are typical of BCGs in cool-core galaxy clusters where the hot intracluster medium (ICM) is dense enough that the gas cools on a timescale shorter than the Hubble time.

The BCGs host active AGN which pump energy mechanically into the ICM via the inflation of radio bubbles which displace and interact with the surrounding thermal gas. They are surrounded by fine threads of ionized gas which have been observed to extend ~60kpc from the nucleus. These ionized gas filaments are often coincident with large reservoirs of cold molecular gas and dust. Some filaments, though not all, are associated with star formation. My research addresses both the origin and the excitation mechanisms of these features.

I will present evidence that the filamentary nebulosities and accompanying star formation in the outer envelopes of these galaxies are a direct result of the AGN-driven mechanical feedback. This process not only inhibits catastrophic cooling of the hot ICM, but also may promote the growth of the outer stellar halos of massive galaxies through its ability to foster spatially extended star formation. This may have far reaching implications for the evolution of massive galaxies.

A thus far successful prescription for the excitation mechanism of the warm ionized filaments has been the particle heating model of Ferland etal. 2009. However, the advent of Herschel has provided a wealth of information with which to characterize the accompanying cold gas. I extend this successful model to these FIR cooling lines providing further testable predictions of the Ferland etal. model.

My research was made possible through the support of the STFC.

329.04D – **Illuminating X-ray Bright and Faint Galaxy Groups: Global Properties and Galaxy Populations at Intermediate Redshift**

Jennifer L. Connelly[1]

[1]Max Planck Institute for Extraterrestrial Physics, Germany.
2:40 PM - 3:00 PM

The majority of galaxies in the Universe lie in galaxy groups which range from 'poor' systems containing few galaxies (commonly identified via optical selection methods) to massive groups (often identified via X-ray emission from the Intra-Group Medium, IGM). In order to study groups spanning a significant mass and evolutionary range, we have defined two samples at a mean redshift of 0.4, one via optical spectroscopy and the other via X-ray emission. By comparing both the global properties and those of the galaxy populations of these two samples, we aim to illuminate the roles of galaxy interactions and mergers (prevalent in the 'poor', dynamically active systems) and the IGM (dominant in the more massive, evolved groups) in shaping the local galaxy population. I focus first on the global properties and scaling relations of our systems, presenting our findings regarding group definition, masses and mass fractions, dynamical complexity, and evidence for a population of X-ray underluminous systems. I then combine knowledge of these global group properties with galaxy composition in order to explore galaxy evolution, differentiating between the effects of age, mass, and the IGM on observed galaxy properties.

329.05 – **The Stellar Mass Assembly of Fossil Galaxies**

Craig Harrison[1], C. Miller[1], J. Richards[2], E. Lloyd-Davies[3], B. Hoyle[4], K. Romer[3], N. Mehrtens[3], M. Hilton[5], J. Stott[6], D. Capozzi[7], C. Collins[7]

[1]University of Michigan, [2]University of California, Berkeley, [3]University of Sussex, United Kingdom, [4]University of Barcelona, Spain, [5]University of KwaZulu-Natal, South Africa, [6]University of Durham, United Kingdom, [7]Liverpool John Moores University, United Kingdom.
3:00 PM - 3:10 PM

Fossil galaxies are massive elliptical galaxies that dominate the optical light of the group or cluster in which they reside. Originally viewed as the end product of galaxy merging, they were thought to contain information on the entire merger history of the group/cluster. Recent work has questioned this interpretation and suggested that they merely represent a transient phase in normal group/cluster evolution. This talk presents the results of a study of the stellar mass assembly and stellar populations of a sample of 15 fossil galaxies at $z < 0.25$. We find that fossil galaxies, at a fixed group/cluster mass, are the most massive cluster galaxies being, on average, twice as massive as brightest cluster galaxies. Despite having stellar populations that are indistinguishable from those of fossil galaxies, our results eliminate normal brightest cluster galaxies at low or high redshift as their likely progenitors. Fossil galaxies are found to contain a significant fraction of the the total optical luminosity of the group/cluster, as much as 75%, compared to the brightest cluster galaxies, which can have as little as 10%. Our results suggest that fossil galaxies form via efficient mergers in early forming systems and that they truly represent the end products of galaxy mergers in groups and clusters.

329.06 – **The Virgo Cluster Through The AGES**

Rhys Taylor[1], J. I. Davies[2], R. F. Minchin[1]

[1]Arecibo Observatory, [2]Cardiff University, United Kingdom.
3:10 PM - 3:20 PM

I describe the final results of the Arecibo Galaxy Environment Survey in two regions of

the Virgo Cluster. This blind HI survey reaches a sensitivity of 2E7 Msolar at 17Mpc. 364 sources are detected, of which 114 are cluster members. I briefly describe our source extraction procedures, which involve comparing two orthogonal polarisations in which the noise is independent, greatly reducing the number of spurious detections. I also describe the early-type galaxies detected in HI within the cluster as well as those detections without any obvious optical counterparts. I comment on the likelihood that these are features are tidal debris or so-called "dark galaxies". Finally I demonstrate a method of viewing FITS files in realtime 3D, which can greatly ease the process of understanding complex features such as tidal tails between multiple interacting objects.

329.07 – **Applying Social Networking and Clustering Algorithms to Galaxy Groups in ALFALFA**

Ali Bramson[1], E. M. Wilcots[1]

[1]*University of Wisconsin-Madison.*

3:20 PM - 3:30 PM

Because most galaxies live in groups, and the environment in which it resides affects the evolution of a galaxy, it is crucial to develop tools to understand how galaxies are distributed within groups. At the same time we must understand how groups are distributed and connected in the larger scale structure of the Universe. I have applied a variety of networking techniques to assess the substructure of galaxy groups, including distance matrices, agglomerative hierarchical clustering algorithms and dendrograms. We use distance matrices to locate groupings spatially in 3-D. Dendrograms created from agglomerative hierarchical clustering results allow us to quantify connections between galaxies and galaxy groups. The shape of the dendrogram reveals if the group is spatially homogenous or clumpy. These techniques are giving us new insight into the structure and dynamical state of galaxy groups and large scale structure. We specifically apply these techniques to the ALFALFA survey of the Coma-Abell 1367 supercluster and its resident galaxy groups.

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330 – Cool Dwarfs, Brown Dwarfs

Oral Session – Room 16A – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

330.01 – **The Late-T Dwarf Population Revealed by WISE**

Gregory N. Mace[1], I. S. McLean[1], J. D. Kirkpatrick[2], WISE Brown Dwarf Team

[1]*UCLA,* [2]*IPAC/Caltech.*

2:00 PM - 2:10 PM

We present over 150 spectroscopically confirmed T dwarfs discovered by the Wide-field Infrared Survey Explorer (WISE). More than 100 of these new discoveries have spectral types ≥ T6, nearly tripling the known sample. Using spectral indices, spectrophotometric colors, and the atmosphere models of Marley & Saumon, we discuss the late-T dwarfs as a population. The characteristics of the "average" late-T dwarf are considered and are compared to spectral standards in the literature. Once this has been done, we can discuss the outliers in terms of gravity and metallicity indicators. Finally, we review the classification of the latest dwarfs in our sample (T9-9.5) in the context of the new Y dwarf spectral class.

330.02 – **The Masses and Metallicities of *Kepler's* Planet-hosting M Dwarfs**

John A. Johnson[1], S. Pineda[1], M. Bottom[1]

[1]*Caltech.*

2:10 PM - 2:20 PM

While much attention is focused on Kepler's Sun-like target stars, there are many target stars that reside at the bottom of the main sequence. Thus, Kepler provides valuable information about planet formation around the Galaxy's most numerous denizens, the M dwarfs. We will present recent advances in understanding the fundamental physical properties of M dwarfs using both broadband photometry and optical spectroscopy. These techniques provide revised estimates of stellar masses and radii, thereby elucidating the radius distribution of planets orbiting low-mass stars. We will present the specific case studies LHS6343C and KOI-254.01, a transiting brown dwarf and hot Jupiter, respectively, orbiting two of Kepler's least massive and most proximate target stars.

330.03D – **M-Dwarf Metallicities With K-band Spectra: Testing Calibrations With Observations of 133 Solar Neighborhood M-Dwarfs**

Barbara Denisse Rojas Ayala[1], K. R. Covey[2], J. P. Lloyd[3], P. S. Muirhead[4]

[1]*Cornell University and American Museum of Natural History,* [2]*Cornell University and Lowell Observatory,* [3]*Cornell University,* [4]*California Institute of Technology.*

2:20 PM - 2:40 PM

Contrary to their dimness, M-dwarf stars hold significant promise for illuminating the processes that govern the formation and evolution of stars, planets, and the Milky Way. Calibrating the fundamental parameters of M-dwarfs, however, is a difficult challenge from both an observational and theoretical perspective. In particular, the determination of their metallicities has proved to be extremely problematic. To address this problem, we obtained K-band spectra for 133 nearby (d<33 parsecs) M-dwarfs, including 18 M-dwarfs with FGK companions, 11 M-dwarf planet hosts, more than 2/3 of the M-dwarfs in the Northern 8pc sample, and several M-dwarfs from the LSPM catalog. From these spectra, we measured equivalent widths of the Ca and Na lines, and a spectral index quantifying the absorption due to H2O opacity. We used the strength of the Na, Ca and H2O features of 18 M-dwarfs with reliable metallicity estimates from FGK companions to construct an empirical [Fe/H] indicator applicable for M dwarfs with near-solar metallicities (-0.69<[Fe/H]<+0.31,sigma=0.141 dex). For the first time, we derive an expression for an M-dwarf's overall metallicity [M/H]; quantitative comparisons to model atmospheres, which are benchmarked according to overall metallicity, provide a qualitative validation of our approach, but also demonstrate an overall offset between the atomic line strengths predicted by models as compared to actual observations. Our metallicity estimates reproduce expected correlations between metallicity and Galactic space motions and Hα emission line strengths, as well as returning statistically identical metallicities for M-dwarf companions within a shorted multiple system. Finally, we provide a list with promising M-dwarfs targets for planet searches in the Solar Neighborhood based on their metallicity, Hα emission, and rotation.

330.04 – **Accurate Stellar Parameters of Low-Mass Kepler Planet Hosts**

Philip Muirhead[1], K. Hamren[2], E. Schlawin[3], B. Rojas-Ayala[4], K. Covey[3], J. Lloyd[3]

[1]*California Institute of Technology,* [2]*University of California, Santa Cruz,* [3]*Cornell University,* [4]*American Museum of Natural History.*

2:40 PM - 2:50 PM

We report stellar parameters for low-mass planet-candidate host stars recently announced by the Kepler Mission. We obtained medium-resolution, K-band spectra of 84 low-mass Kepler Objects of Interest (KOIs). We identified one KOI as a giant; for the remaining dwarfs, we estimated effective temperatures by comparing measurements of K-band regions dominated by H2O opacity with predictions of synthetic spectra for low-mass stars. We measured overall metallicities ([M/H]) using the equivalent widths of Na I and Ca I absorption features and an empirical metallicity relation calibrated with nearby stars. With effective temperatures and metallicities, we estimate the masses and radii of the low-mass KOIs by interpolation onto two sets of evolutionary isochrones. The resultant stellar radii are significantly less than the values reported in the Kepler Input Catalogue and, by construction, correlate better with effective temperature. Using either set of isochrones, our results significantly reduce the sizes of the corresponding planet candidates, with many less than 1 Earth radius. We report recalculated equilibrium temperatures for the planet-candidates and the implications for Kepler's yield of terrestrial exoplanets in the habitable zones of their host stars.

330.05D – **Testing Low Mass Stellar Models with M-dwarf Eclipsing Binaries from SDSS Stripe 82**

Waqas Bhatti[1], H. C. Ford[1], L. D. Petro[2], M. W. Richmond[3]

[1]*Johns Hopkins University,* [2]*Space Telescope Science Institute,* [3]*Rochester Institute of Technology.*

2:50 PM - 3:10 PM

Eclipsing binaries (EBs) provide direct measurements of the absolute masses and radii of the component stars. Recent observations of M-dwarf EBs have indicated that their measured radii are larger than those predicted by stellar models. Tidally induced magnetic fields in close binaries may be responsible for this discrepancy. This scenario may be tested by characterizing the relation between orbital period and the ratio of predicted to observed stellar radii. The small number of fully characterized M-dwarf EBs, however, makes any trend in this relation difficult to quantify.

Here, we describe a search for M-dwarf EBs carried out using multi-band timeseries photometry from SDSS Stripe 82. We describe the construction of our light-curve catalog and the methodology for extracting variable point sources. We discuss the classification of the ~650 periodic variables discovered in these data, and the subsequent discovery of nearly 300 EB candidates. For the ~90 EBs that had suitable light-curves, we fit binary models using the Wilson-Devinney code (Wilson 1971, 2007), and estimated relative radii, temperatures, luminosities, photometric mass ratios, and orbital inclinations of the binary systems. From this sample, we identified two bright candidates for additional follow-up observations.

We present the results of these observations, which include R and I band light-curves obtained with the Apache Point 3.5-m and Kitt Peak 2.1-m telescopes, as well as radial velocity measurements carried out with the Apache Point 3.5-m telescope. We obtain estimates of the absolute masses and radii of the stars in these systems. Finally, we compare these measurements to predictions generated by stellar models of the lower main sequence, and characterize the influence of tidally-induced magnetic fields on the measured radii of the M-dwarf components of these systems.

330.06D – **Kinematics, Colors, And Ages Of Ultracool Dwarfs**

Sarah J. Schmidt[1], S. L. Hawley[1]

[1]*University of Washington.*

3:10 PM - 3:30 PM

We present results from multiple spectroscopic and photometric datasets for late-M and L dwarfs in the field. These include L dwarfs selected in SDSS data release 7, ultracool dwarfs within 20pc of the Sun as part of the Brown Dwarfs Kinematics Project, and first results from our SDSS-III ancillary program to obtain spectra of late-M and L dwarfs. Combining radial velocities, proper motions, and colors from each of these complementary datasets, we examine the ages of field L dwarfs and investigate relations between color and age.

331 – Cosmology II

Oral Session – Ballroom D – Wednesday, January 11, 2012, 2:00 PM - 3:30 PM

331.01 – **Dark Energy Survey Supernovae: Overview and Forecast of Cosmological Results**

Joseph P. Bernstein[1], Dark Energy Survey Collaboration

[1]*Argonne National Lab.*

2:00 PM - 2:10 PM

We present an analysis of supernova light curves simulated for the upcoming Dark Energy Survey (DES). We employed a code suite known as SNANA, that generates and fits realistic supernova light curves, to simulate the DES supernova sample. We forecast that the DES will provide a homogeneous sample of approximately 4000 Type Ia supernovae in the redshift range 0.05<z<1.2. We give an overview of the preferred survey strategy and discuss forecasts of the cosmological constraints for various strategies considered.

331.02 – **Redshift Determination for the DES Supernova Survey**

Eve Kovacs[1], Dark Energy Survey Collaboration

[1]*Argonne National Laboratory.*

2:10 PM - 2:20 PM

The upcoming Dark Energy Survey supernova search will provide a homogeneous sample of approximately 4000 supernovae in the redshift range 0.05<z<1.2. Accurate redshift determinations for these supernovae are essential for extracting cosmological parameters. Unlike previous surveys, the strategy for redshift determination for most of the sample will not rely on spectrscopic follow-up of individual supernovae, but instead will use a combination of two methods: spectroscopic follow-up of host galaxies and photometric redshift determinations. Estimates of the number of supernovae that fall into each class can be made using galaxy luminosity functions and measured supernova rates. We discuss the assumptions and uncertainties in these estimates and present the impact on the forecast Dark-Energy-Task-Force figures of merit.

331.03 – **Photometric Typing For The Dark Energy Survey Supernovae.**

Stephen Kuhlmann[1]

[1]*Argonne National Laboratory.*

2:20 PM - 2:30 PM

The supernova component of the Dark Energy Survey will begin in 2012. Over five years it will provide a homogeneous sample of ~4000 Type Ia supernova from redshifts 0.05<z<1.2. Since these data are too numerous to measure each supernova spectra, photometric typing will be a key element of the survey. We describe photometric typing studies in the Dark Energy Survey and sample purities.

331.04 – **The Supernova Component Of The Des Survey: Forecasts Of Cosmological Constraints**

Rahul Biswas[1], Dark Energy Survey Collaboration

[1]*Argonne National Laboratory.*

2:30 PM - 2:40 PM

We present an analysis of supernova light curves simulated for the upcoming Dark Energy Survey (DES) supernova search. On the basis of these simulations, we expect that this survey will provide a homogeneous sample of approximately 4000 supernovae in the redshift range 0.05<z<1.2. We will discuss the methodology used in forecasting the constraints on cosmological parameters using these simulations, incorporating the effects of expected systematics.

331.05D – **Constraining Interlopers in High Redshift Samples Using Cross-correlations**

Daniel Matthews[1]

[1]*University of Pittsburgh.*

2:40 PM - 3:00 PM

The combination of photometric and spectroscopic surveys in the same region of sky provides powerful tools for studying cosmology and galaxy evolution. We have previously demonstrated that via cross-correlation techniques, photometric redshifts for future dark energy surveys can be calibrated to the necessary accuracy using spectroscopy only of the brightest objects at a given z. Another area where such complementary datasets can be particularly useful is in the analysis of high-redshift galaxy samples. A key challenge in identifying high redshift galaxies photometrically is distinguishing them from lower-redshift (z~2) interlopers with similar broadband colors. In the past these interlopers have generally been identified via extremely deep imaging at other bands or via spectroscopy. However, for the faint dropout samples now being identified using WFC3, both of these avenues become less practical. A powerful alternative is to exploit the clustering of galaxies to determine the interloper fraction. Low redshift interlopers will cluster with easier-to-identify, bright low-redshift objects, whereas true high-redshift galaxies will not. Hence, by measuring the two-point angular cross-correlation between objects in a sample of high-z candidates and objects with known spectroscopic redshifts, we can constrain the interloper fraction for samples too faint for spectroscopy. With coarse priors on galaxy biasing (e.g. assuming observed trends of bias with color and luminosity extend to fainter galaxies at low redshift), the interloper fraction can be determined even if spectroscopic samples do not cover the full redshift range of the high-z candidates. This technique can be useful for measuring interloper fractions in new surveys of the high-redshift universe such as the CANDELS Multi-Cycle Treasury Program on the Hubble Space Telescope.

331.06 – **The Most Powerful Cosmic Telescopes for Constraining the Faint-end Slope of the z > 7 Luminosity Function**

Stephen Ammons[1], K. C. Wong[2], A. I. Zabludoff[2], C. R. Keeton[3], D. French[2]

[1]*Lawrence Livermore National Laboratory,* [2]*University of Arizona,* [3]*Rutgers University.*

3:00 PM - 3:10 PM

It is likely that intergalactic hydrogen was reionized by redshifts of $6 < z < 10$, but it is not known whether the flux density of UV photons from the earliest galaxies was sufficient to do so. Measurements of the faint end slope of the luminosity function at these redshifts can help to address this question. I explore the use of the densest galaxy fields to lens faint objects into detectability, increasing source counts and providing improved constraints on dlog N / dlog L. First, I present galaxy spectroscopy for the first two dense beams identified from the SDSS. We have now confirmed that these beams have integrated masses of 3-4 x 10^{15} solar masses, surpassing even the most massive single cluster lensing fields. This increased mass should result in 50-1000% more detected sources at $z > 7$ than other current methods with equivalent exposure time. Second, I compare the high-redshift detection efficiencies of lensing and blank fields including realistic assumptions for the intrinsic sizes and morphologies of sources at $z > 7$. We find that there are heretofore uncorrected biases introduced by lensing due to the difficulty of detecting faint, highly elongated objects at high magnification. To interpret high-redshift, magnified number counts correctly, incompleteness due to this bias must be addressed with lensing simulations. The correction for incompleteness near the detection limit may exceed a factor of ten. Including finite source size and realistic shape assumptions, luminosity function slopes must be steeper than -dlog N / dlog L ~ 2 at the faint end for cosmic telescopes to surpass blank field surveys in $z > 7$ detection efficiency. Prepared by LLNL under Contract DE-AC52-07NA27344.

332 – Galaxy Formation Star-by-Star: the View from the Milky Way

Invited Session – Ballroom D – Wednesday, January 11, 2012, 3:40 PM - 4:30 PM

332.01 – **Galaxy Formation Star-by-star: The View From The Milky Way**

Kathryn V. Johnston[1]

[1]*Columbia Univ..*

3:40 PM - 4:30 PM

The stars, gas and dust that make galaxies are thought to sit inside much more massive and extended dark matter halos. Observational constraints on the formation, structure and distribution of these dark matter halos agree remarkably well with our expectations for the evolution of collisionless particles in a ΛCDM cosmology. In contrast, our understanding of the evolution of the stars, gas and dust is much less well-developed. This talk looks at what the distribution of stars in phase and chemical-abundance space in the Milky Way might tell us about the messy, baryonic physics that forms galaxies more generally.

333 – Star Formation in Galaxy Clusters Over the Past 10 Billion Years

Invited Session – Ballroom D – Wednesday, January 11, 2012, 4:30 PM - 5:20 PM

333.01 – **Star Formation in Galaxy Clusters Over the Past 10 Billion Years**

Kim-Vy Tran[1]

[1]*Texas A&M University.*

4:30 PM - 5:20 PM

Galaxy clusters are the largest gravitationally bound systems in the universe and include the most massive galaxies in the universe; this makes galaxy clusters ideal laboratories for disentangling the nature versus nurture aspect of how galaxies evolve. Understanding how galaxies form and evolve in clusters continues to be a fundamental question in astronomy. The ages and assembly histories of galaxies in rich clusters test both stellar population models and hierarchical formation scenarios. Is star formation in cluster galaxies simply accelerated relative to their counterparts in the lower density field, or do cluster galaxies assemble their stars in a fundamentally different manner? To answer this question, I review multi-wavelength results on star formation in galaxy clusters from Coma to the most distant clusters yet discovered at look-back times of 10 billion years (z~2).

400 – The Evolving Context for Science and Society

Invited Session – Ballroom D – Thursday, January 12, 2012, 8:30 AM - 9:20 AM

400.01 – **The Evolving Context for Science and Society**

Alan I. Leshner[1]

[1]*AAAS.*

8:30 AM - 9:20 AM

The relationship between science and the rest of society is critical both to the support it receives from the public and to the receptivity of the broader citizenry to science's explanations of the nature of the world and to its other outputs. Science's ultimate usefulness depends on a receptive public. For example, given that science and technology are imbedded in virtually every issue of modern life, either as a cause or a cure, it is critical that the relationship be strong and that the role of science is well appreciated by society, or the impacts of scientific advances will fall short of their great potential. Unfortunately, a variety of problems have been undermining the science-society relationship for over a decade. Some problems emerge from within the scientific enterprise - like scientific misconduct or conflicts of interest - and tarnish or weaken its image and credibility. Other problems and stresses come from outside the enterprise. The most obvious external pressure is that the world economic situation is undermining the financial support of both the conduct and infrastructure of science. Other examples of external pressures include conflicts between what science is revealing and political or economic expediency - e.g., global climate change - or instances where scientific advances encroach upon core human values or beliefs - e.g., scientific understanding of the origins and evolution of the universe as compared to biblical accounts of creation. Significant efforts - some dramatically non-traditional for many in the scientific community - are needed to restore balance to the science-society relationship.

422 – Instrumentation: Ground Based or Airborne

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

422.01 – **VRI/*gri* Photometry And Polarimetry Of Blazars At The Table Mountain Observatory, 2005-2011**

Alma C. Zook[1], F. S. Giron[1], C. A. Owens[1]

[1]*Pomona College.*

9:00 AM - 2:00 PM

We present VRI/*gri* photometry and polarimetry of several objects studied by the blazar monitoring program at Pomona College's Table Mountain Observatory, which has now been operating for seven summers. Initially only VRI photometric observations were possible, although a set of *gri* filters was added in 2008 and is now the filter set most commonly in use. A polarimeter was added during the summer of 2007 and most of last summer's observations involved characterizing the performance of the polarimeter in greater deal, including testing the effects of scattered moonlight.

422.02 – **Transmission Grating Spectrometers in Undergraduate Astronomy Laboratories**

Ryan Hood[1], J. Moore[1], M. McKinlay[1], D. Coffin[1], D. Trieweiler[1], R. L. Mutel[1]

[1]*University of Iowa.*

9:00 AM - 2:00 PM

The Iowa Robotic Telescope, located in southern Arizona, has been used in University of Iowa undergraduate laboratories for more than a decade. The addition of a low-resolution transmission grating spectrometer (TGS) to the 0.37 m classical Cassegrain reflector has allowed students to obtain spectra of stars, planets, and nebulae as regular part of the lab curriculum. We discuss the relative efficiency and resolution dependences using different groove spacings, slits, telescope optics, and camera sensor geometries. In addition, we consider the use of beam steering prisms joined with diffraction gratings (grisms). Students may schedule the TGS system using a simple web-based form to observe targets down to approximately 10th magnitude. Some of the TGS observational targets include Wolf-Rayet stars with optically thick winds, novae, as well as main sequence stars over the entire spectral sequence.

422.03 – **Spectroscopy at LCOGT**

Timothy M. Brown[1], M. Becker[1], B. Burleson[1], J. De Vera[1], M. Dubberley[1], J. Eastman[1], B. Haldeman[1], E. Hawkins[1], R. Haynes[1], J. Hygelund[1], T. Lister[1], R. Lobdill[1], M. Norbury[1], A. Pickles[1], W. Rosing[1], D. Sand[1], J. Tufts[1]

[1]*LCOGT.*

9:00 AM - 2:00 PM

Las Cumbres Observatory Global Telescope (LCOGT) is developing a world-wide network of optical telescopes dedicated to time-domain astronomy. In a few years, the network will consist of more than twenty 0.4m telescopes, about fifteen 1m telescopes, and two 2m telescopes. We are now developing spectrographs to use with this network; here we describe the performance goals and status of these instruments. Furthest along is FLOYDS, a low-resolution spectrograph that will cover 330nm - 1040 nm in one shot, using two diffraction orders. FLOYDS is intended mostly for SN classification and time-evolution studies. We will install copies of this spectrograph on each of LCOGT's 2m Faulkes telescopes, beginning with FTN early in 2012. Still in the prototype stage is MRES, a medium-resolution (R=45,000) fiber-fed cross-dispersed echelle covering 380nm-850nm. It will accept fibers from up to 3 co-located 1m telescopes, so that we can observe multiple targets at once, or gain S/N by devoting multiple telescopes to a single target. The spectrograph is designed for easy control of its light path and environment, to facilitate accurate and repeatable measurements. MRES will be used mostly for validation and study of extrasolar planets, and for time-domain studies of pulsating and magnetically active stars.

422.04 – **The Upgraded Tennessee State University 2m Automatic Spectroscopic Telescope**

Matthew W. Muterspaugh[1], M. H. Williamson[1], F. C. Fekel[1], C. Harrison[1]

[1]*Tennessee State University.*

9:00 AM - 2:00 PM

We recently have completed several upgrades to the Tennessee State University (TSU) 2m automatic spectroscopic telescope (AST), which is located at Fairborn Observatory, Washington Camp, Arizona. A new 4K x 4K Fairchild 486 CCD with 15 micron pixels, housed in a dewar cooled by a CryoTiger refrigeration system, has allowed us to substantially increase the wavelength coverage and greatly reduce the noise of our echelle spectra. A new beam splitter cube has increased the throughput of the system by about 1 magnitude. A recently built instrument head enables us to rapidly switch between commercial fibers of different diameters, allowing us to use different resolutions for different stars. Microlenses, attached to the ends of those fibers, have improved the f-ratio compatibility of the fibers and the spectrograph system. We discuss these enhancements and the resulting throughput improvements. The TSU 2m AST is available for joint projects with outside observers. As a robotic telescope dedicated to spectroscopic observations, the AST provides rare opportunities for observing programs that benefit from high cadences. In its previous incarnation it has participated in several photometric-spectroscopic observing campaigns such as the one completed in 2010 on the B8 supergiant Rigel. Simultaneous with MOST satellite photometry, the 2m AST obtained 442 spectra on 20 nights. This intensive series of spectroscopic observations plus somewhat less numerous spectra, taken for several years before the joint campaign, enabled the identification of Rigel's spectrum of pulsation frequencies.

422.05 – **Optimal Resolutions for Optical and IR Spectroscopy**

Steven Villanueva[1], D. L. Depoy[1], J. Marshall[1]

[1]*Texas A&M University.*

9:00 AM - 2:00 PM

We study the effects of atmospheric emission lines in the 0.4-2.4 micron range at resolutions ranging from 100-100,000 on a pixel-by-pixel basis. After building an atmospheric emission model, we define and calculate the fraction of pixels free of emission lines in 7 different band passes. We then discuss the the effect of the background emission on the SNR of targets of various magnitudes to determine a 'best' resolution at which to observe.

422.06 – **Progress in Astronomical Radiometry: Demonstration of Precise Lidar-based Real-time Atmospheric Extinction Corrections**

John T. McGraw[1], P. C. Zimmer[1], D. M. Vorobiev[2], D. C. Zirzow[1], J. C. Karle[1], P. S. Romero[1], C. E. Cramer[3], K. R. Lykke[3], J. T. Woodward[3], S. E. Deustua[4], D. C. Hines[4], Measurement Astrophysics Research Team

[1]Univ. of New Mexico, [2]Rochester Institute of Technology, [3]National Institute of Standards and Technology, [4]Space Telescope Science Institute.

9:00 AM - 2:00 PM

We demonstrate atmospheric extinction corrections to a precision of 0.25% per airmass at one minute cadence using the Astronomical Lidar for Extinction (ALE). The lidar tracked within or near the 0.7 degree by 1.0 degree field of view of a 300mm diameter astrograph acquiring imaging radiometric data of stars. The field included a target star, often a short-period variable star, and several comparison stars. Extinction corrections are simultaneously derived from the lidar returns and by differential radiometry amongst the comparison stars.

ALE is an alt-az mounted bistatic elastic backscatter lidar operated at 527nm transmitting 24 ns pulses at 1500 Hz with a 305 mm transmitter, 100 mm short range receiver and 670 mm long range receiver. Both receivers use photomultipliers as detectors and extinction corrections derive from pulse counting the stratospheric Rayleigh backscatter return from approximately 15 km to 30 km altitude.

We show that:

• Nightly mean extinction coefficients do not adequately represent the time and angular variability of extinction and can introduce systematic errors of at least one percent even on “visually photometric” nights.

• Extinction corrections must be derived by measurement of the column of atmosphere through which astronomical observations are being made.

• The ALE lidar provides precise extinction corrections through atmospheric transmission variations of at least 50% (0.75 mag of extinction).

• Lidar extinction corrections depend only upon instrumental parameters, principally lidar power, thus provide precise extinction corrections for the column of atmosphere through which the supported telescope observes, independently of the (*e.g.* stellar) content of the field.

We assert that lidar-based atmospheric extinction corrections obviate atmospheric extinction as the major source of radiometric error for ground-based telescopes.

This research is supported by NIST Award 60NANB9D9121 and NSF Grant AST-1009878.

422.07 – **Calibrating Atmospheric Transmission**

Peter C. Zimmer[1], J. T. McGraw[1], D. M. Vorobiev[2], D. C. Zirzow[1], J. C. Karle[1], K. R. Lykke[3], J. T. Woodward[3], C. E. Cramer[3]

[1]Univ. of New Mexico, [2]Rochester Institute of Technology, [3]NIST.

9:00 AM - 2:00 PM

Earth’s atmosphere is a wavelength-, directionally- and time-dependent turbid refractive element for every ground-based telescope. Changes in atmospheric transmission are the most significant systematic error limiting photometric measurement precision and accuracy. While considerable resources have been devoted to correcting the effects of the atmosphere on angular resolution, the effects on precision photometry have largely been ignored. To correct photometric measurements for the transmission of the atmosphere requires direct measurements of the wavelength-dependent transmission in the same direction and at the same time that the supported photometric telescope is acquiring its data.

We describe the multi-wavelength lidar, the Facility Lidar for Astronomical Measurement of Extinction (FLAME) that observes the stable stratosphere, and a spectrophotometer (the Astronomical Extinction Spectrophotometer - AESoP) that creates and maintains NIST absolute standard stars, the combination of which enables fundamentally statistically limited photometric precision of both the stellar spectra and atmospheric transmission. The throughput of both FLAME and AESoP are calibrated to NIST radiometric standards.

This inexpensive and replicable instrument suite provides the lidar-determined monochromatic transmission of Earth’s atmosphere at visible and near-infrared wavelengths to 0.25% per airmass and the wavelength-dependent transparency to less than 1% uncertainty per nanometer per minute of time. These atmospheric data are merged to create a metadata stream that allows throughput corrections from data acquired at the time of the scientific observations to be applied to broadband and spectrophotometric scientific data. This new technique replaces the classical use of nightly mean atmospheric extinction coefficients, which invoke a stationary and plane-parallel atmosphere and ultimately limit ground-based all-sky photometry to 1% - 2% precision.

This research is supported by NIST Award 60NANB9D9121 and NSF Grant AST-1009878.

422.08 – **Progress Towards A NIST-calibrated Catalog Of Spectrophotometric Standard Stars**

Claire Cramer[1], K. R. Lykke[1], P. Shaw[1], J. T. Woodward[1], E. E. Falco[2], C. W. Stubbs[3], A. Vaz[3], J. T. McGraw[4], P. C. Zimmer[4]

[1]NIST, [2]Harvard-Smithsonian Center for Astrophysics, [3]Harvard University, [4]University of New Mexico.

9:00 AM - 2:00 PM

We present recent progress in the National Institute and Technology (NIST) program to create a catalog of stars with SI-traceable spectral energy distributions known at the sub-percent level. We have constructed and characterized a new spectrograph that is now installed on the NIST telescope on Mt. Hopkins. We have also developed a technique to measure atmospheric extinction along a horizontal line of sight, which allows us to better calibrate our spectrograph using a terrestrial light source as an artificial star.

422.09 – **Dark Energy Spectrometer - A Proposed Multi-Fiber Instrument for the Blanco 4 Meter Telescope**

Stephen M. Kent[1], T. Diehl[1], J. Marshall[2], D. DePoy[2], W. Saunders[3], M. Colless[3], J. Frieman[1], O. Lahav[4], F. Abdalla[4], J. Annis[1], H. Lin[1], S. Jouvel[5]

[1]Fermi Nat'l. Accelerator Lab., [2]Texas A&M U., [3]AAO, Australia, [4]U. College London, United Kingdom, [5]U. College London.

9:00 AM - 2:00 PM

We describe a new initiative, the Dark Energy Spectrometer (DESpec), a 4000-fiber instrument concept for the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory (CTIO) in Chile. In a survey of about 300 nights, DESpec could obtain spectroscopic redshifts for of order 10 million galaxies over 5000 sq. deg. selected from Dark Energy Survey (DES) imaging and, under certain assumptions, would improve the Dark Energy Task Force (DETF) Figure of Merit by a factor of several over DES. The instrument would be swappable with the DES camera (DECam) and would share the optical corrector.

422.10 – **Commissioning the Robert Stobie Spectrograph on the 11-meter Southern African Large Telescope (SALT)**

Eric Jon Hooper[1], K. Nordsieck[1], T. Williams[2], D. Buckley[3], SALT Operations Group, UW-Madison RSS Commissioning Group

[1]Univ. of Wisconsin-Madison, [2]Rutgers University, [3]Southern African Large Telescope, South Africa.

9:00 AM - 2:00 PM

The Southern African Large Telescope (SALT) is an 11-meter optical and near-infrared telescope located in South Africa. It is operated by an international consortium led by South Africa and consisting of partners in the U.S., Europe, India, and New Zealand. After some initial telescope image quality problems were fixed, one of the main workhorse instruments called the Robert Stobie Spectrograph began checkout and commissioning in April, 2011. All of the instrument modes have been shown to be operational, and some of them are now in routine use. Shared-risk science observations began in September, 2011, alongside ongoing commissioning of the more unusual modes of this very versatile and complex instrument. The RSS provides numerous capabilities in a compact prime-focus design with an 8 arcminute field of view:

• Long-slit spectroscopy. Six gratings provide resolving powers ranging from 800 to 11,000 and wavelength coverage from the blue atmospheric cutoff (320 nm) to around 1000 nm.

• Multi-object spectroscopy using laser-cut slit masks.

• High speed spectroscopy. By restricting the field of view in a slot mode, spectra can be read out as rapidly as 10 Hz.

• Fixed band imaging. In addition to providing help with target acquisition, the RSS imaging mode is a powerful narrow-band imaging system, with a suite of narrow-band filters nearly continuously covering the wavelength range 430 - 900 nm.

• Fabry-Perot imaging. The system can operate with either one or two etalons, providing a range in spectral resolving power from 250 to 10,000 over 430- 900 nm.

• Polarimetry. All of the modes listed above also support polarimetric modes (linear and circular).

Two next-generation instruments are under construction: a high-resolution fiber-fed spectrograph with resolving power reaching 65,000; and a near-infrared sibling of RSS, which will extend the spectral coverage to 1.7 microns.

422.11 – **High Time Resolution Astronomy on the 10m Southern African Large Telescope (SALT)**

John Vallerga[1], B. Y. Welsh[1], M. Kotze[2], A. Gulbis[3], S. Potter[2], D. Buckley[4], D. Anderson[1]

[1]University of California, Berkeley, [2]South African Astronomical Observatory, South Africa, [3]South African Astronomical Observatory and Southern African

Large Telescope, South Africa, [4]Southern African Large Telescope, South Africa.
9:00 AM - 2:00 PM

We present astronomical observations recorded at a time resolution of < 1 microsecond with the Berkeley Visible Image Tube (BVIT) on the 10m Southern African Large Telescope (SALT). Objects of interest include low-mass X-ray binaries (e.g. GR Mus), which were observed simultaneously with the RXTE satellite. In addition, we show high time resolution data for the eclipsing binary systems of V895 Cen and CTCVJ1928.

BVIT will become a user instrument on SALT in 2012 and we present details of the system, its performance characteristics and how potential users may apply for telescope time.

422.12 – **The Subaru Coronagraphic Extreme Ao Project: First On-sky Results**

Christophe Clergeon[1], O. Guyon[1], F. Martinache[1]

[1]Subaru Telescope.
9:00 AM - 2:00 PM

The Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) system uses advanced coronagraphic technique for high contrast imaging of exoplanets and disks as close as 1 lambda/D from the host star.

In addition to unusual optics,achieving high contrast at this small angular separation requires a wavefront sensing and control architecture which is optimized for exquisite control and calibration of low order aberrations.

The SCExAO system was thus designed to include the wavefront sensors required for bias-free high sensitivity and high speed wavefront measurements.

Information is combined from two infrared wavefront sensors and a fast visible wavefront sensors to drive a single MEMS type deformable mirror mounted on a tip-tilt mount.

The wavefront sensing and control architecture is highly integrated with the coronagraph system.

First on-sky results acquired downstream Subaru's AO188 AO system during last summer engineering tests will be presented.

422.13 – **The GMACS Spectrograph for the GMT**

Jennifer L. Marshall[1], D. L. DePoy[1], S. A. Shectman[2], C. Papovich[1], S. A. Smee[3], R. H. Barkhouser[3], T. M. Prochaska[1], R. P. Hammond[3]

[1]Texas A & M University, [2]GMT Observatory, [3]JHU/IDG.
9:00 AM - 2:00 PM

We describe a conceptual design for a wide field, multi-object, moderate-resolution optical spectrograph (known as GMACS) for the Giant Magellan Telescope (GMT). The crucial design drivers for the instrument are high throughput, simultaneous wide wavelength coverage over the entire optical window, and accurate and precise sky subtraction. The range of science projects enabled by the instrument is huge: from mineralogical studies of distant asteroids and KBOs to stellar population studies of high redshift galaxies.

422.14 – **Design of the MooSci Lunar Scintillometer**

Kyle W. Cook[1], D. L. DePoy[1], J. L. Marshall[1], S. Villanueva Jr.[1], J. Rheault[1], R. D. Allen[1], D. W. Carona[1], J. E. Thomas-Osip[2], G. Prieto[2], A. Berdja[2]

[1]Texas A&M University, [2]Giant Magellan Telescope Organization.
9:00 AM - 2:00 PM

To develop next generation telescopes and adaptive optics (AO) systems, it is crucial to understand the characteristics of an astronomical site. Lunar scintillometers are an important tool to aid in this understanding. These instruments are able to measure atmospheric turbulence and its effect on astronomical seeing at the ground layer where telescope and observatory design play a role. Here we describe a new lunar scintillometer, MooSci, to aid in the site characterization campaign for the Giant Magellan Telescope (GMT). MooSci has been tested and confirmed to provide reliable data for the reconstruction of turbulence profiles.

422.15 – **Development Status of the Prototype of the GMT Fast Steering Mirror**

Young-Soo Kim[1], J. Koh[1], I. Chung[1], M. Cho[2], H. Yang[3], H. Kim[4], H. Ahn[5], I. Han[1], J. Kyeong[1], M. Chun[1], B. Park[1]

[1]KASI, Korea, Republic of, [2]NOAO, [3]KRISS, Korea, Republic of, [4]IAE, Korea, Republic of, [5]GIST, Korea, Republic of.
9:00 AM - 2:00 PM

Fast Steering Mirror (FSM) is one of the secondary mirror systems of the Giant Magellan Telescope. FSM is 3.2 m in diameter and has a fast focal ratio of 0.65. FSM consists of seven segments. Each segment is 1m in diameter and the surrounding six segments except the center one are off-axis mirrors. FSM compensates image degradations caused by wind disturbances and structure jitter by using a tip-tilt mechanism.

Korea Astronomy and Space Science Institute is developing a prototype of the FSM together with collaborators in Korea and USA. The prototype is a full-size FSM segment, which has two features; an off-axis mirror and a test-bed for tip-tilt actuation. The off-axis mirror with a diameter of 1.06m is being fabricated. Light-weighting is proceeding, and polishing, figuring, and testing will follow. The tip-tilt test-bed is integrated with a dummy aluminum mirror, three axial supports, a lateral support, and a test-bed frame. The test-bed will demonstrate to verify the tip-tilt parameters and measure reaction forces from tip-tilt actuation. The prototype is expected to be completed by 2012. In this paper, we present progress of the prototype development, and future works.

422.16 – **Gemini North Multi-Object Spectrograph (GMOS-N) CCDs Upgrade: Project Status and Future Plans**

Scot Kleinman[1], T. Hardy[2], R. Murowinski[2], K. Szeto[2], B. Walls[1], K. Roth[1], K. Chiboucas[1], R. Schiavon[1], G. Gimeno[3], J. White[1], D. Simons[1], M. Rippa[1], K. Labrie[1], J. Dunn[2], K. Hanna[1], C. Cavedoni[1], S. Bombino[1]

[1]Gemini Observatory, [2]NRC Herzberg Institute of Astrophysics, Canada, [3]Gemini Observatory, Chile.
9:00 AM - 2:00 PM

The GMOS-N CCDs have been recently upgraded with new e2v deep-depletion devices, replacing the original EEV CCDs in use since the instrument was commissioned in late 2001. These new detectors have improved sensitivity in both the red and the blue, and were immediately used for queue observing while commissioning and detector on-sky characterization proceeded in parallel. These devices provide an incremental, yet significant upgrade which will be followed by the planned replacement of the focal plane with fully-depleted Hamamatsu red and blue sensitive devices. The interim e2v upgrade was designed to satisfy the needs of the Gemini scientific community in a timely fashion until issues encountered with the Hamamatsu CCD upgrade could be more fully addressed. Here, we present a project status update on the GMOS-N CCDs upgrade project, including details of the e2v deep-depletion CCD installation and plans for the eventual Hamamatsu upgrade. We discuss some of the complications and lessons learned during the course of the Hamamatsu project, and present the current schedule for installation of the Hamamatsu CCDs. In addition to further improved QE in the red, the Hamamatsu project will deliver faster readout times, 10% more spectral coverage, and improved detector controller software providing integrated support for nod & shuffle. By combining multiple CCDs with different anti-reflective coatings, the coming Hamamatsu focal plane array will retain the increased blue sensitivity recently realized by the e2V installation and provide an additional factor of 2 increase in QE longward of 940 nm.

422.17 – **Gemini North Multi-Object Spectrograph (GMOS-N) Interim CCDs Upgrade: Commissioning Results I**

Kristin Chiboucas[1], K. Roth[1], R. Schiavon[1], I. Jorgensen[1], G. Gimeno[2], S. Kleinman[1]

[1]Gemini Observatory, [2]Gemini Observatory, Chile.
9:00 AM - 2:00 PM

The Gemini GMOS-North CCDs are undergoing a succession of upgrades to improve sensitivity, particularly in the red. In late fall 2011, the original GMOS-N E2V CCDs were replaced with deep depletion E2V devices. The array consists of three 2048x4608 CCD chips in the same layout as the original CCDs, having enhanced blue and red response. The improvement in QE is > 50% at 400nm and > 90% at 900nm, with sensitivity extending redward of 950nm. In addition, fringing is much less than with the original CCDs. Other properties, including noise characteristics, pixel scale, and readout time are similar to the original CCDs. We present a comparison of imaging obtained with the original and deep depletion E2V CCDs, highlighting the realized gains in increased red sensitivity and reduced fringing.

422.18 – **Gemini North Multi-Object Spectrograph (GMOS-N) Interim CCDs Upgrade: Commissioning Results II**

Katherine Roth[1], R. Schiavon[1], K. Chiboucas[1], G. Gimeno[2]

[1]Gemini Obs., [2]Gemini Obs., Chile.
9:00 AM - 2:00 PM

The GMOS-N instrument was upgraded with new e2v deep-depletion devices in November 2011. The new detectors extend and improve the sensitivity at both ends of the optical spectrum by factors of up to 1.45 in the blue and > 2 longward of 850 nm. These CCDs, being deep-depletion devices, are significantly thicker than the original CCDs and produce spectral images affected much less by fringing. This provides a significantly improved sky subtraction at long wavelengths, which is dominated by a dense population of atmospheric emission lines. We present commissioning results including detector characteristics, spectroscopic throughputs, cosmic ray rates, nod & shuffle dark features, and spectral PSFs.

422.19 – **Fully Optimized Shaped Pupils for Arbitrary Apertures**

Alexis Carlotti[1], R. Vanderbei[1], N. J. Kasdin[1], G. Che[1]

[1]*Princeton University.*
9:00 AM - 2:00 PM

Optimal apodization masks for monolithic and segmented apertures are presented, with and without central obstruction and spider vanes. Examples of optimal masks are shown for several ground-based telescopes (The Subaru, Keck, Gemini, Palomar and Very Large telescopes). We also discuss the case of extremely large telescopes. Various high-contrast regions are considered with different inner and outer working angles, shapes and contrasts. These parameters are chosen to fit the specific constraints of each instrument, in particular those set by the dedicated coronagraphic adaptive optics system. Because of the limited size of the high-contrast regions, all the masks that result from these optimizations tend to have binary transmissions, and are thus as achromatic as previous shaped pupils. Effort is put on obtaining structurally connected masks. We intend to test these new shaped pupils in Princeton's high-contrast imaging laboratory, and to this end we explore different techniques to make the masks, such as cutting them in a metal layer, laying them on a glass substrate, or using a MOEMS device.

422.20 – **Hivis: Precision Limitations**

Becky Nevin[1], D. Harrington[2]

[1]*Whitman College,* [2]*University of Hawai'i - Institute for Astronomy.*
9:00 AM - 2:00 PM

The high-resolution visible and infrared spectrograph (HiVIS) is located in one of the coudé rooms of the air force's AEOS (advanced electro-optical system) telescope, which is a 3.67m telescope situated on the island of Maui. Spectropolarimetric signals are typically on the order of 0.1% of the continuum intensity. Therefore, although spectropolarimetry is a powerful remote-sensing tool, useful for the detection of processes taking place within the stellar environment, it requires a high signal to noise ratio to detect these small signatures as well as the identification of systematic noise in order to achieve the precision necessary to avoid masking polarization signatures.

HiVIS uses a new CCID20 detector with bi-directional clocking and charge shuffling capabilities and liquid crystal variable retarders for the purpose of modulating an incoming polarization signature. We present a characterization of the CCID20 detector and the LCVRs, revealing trade-offs and limitations of the rapid modulation process. The preliminary results show that within the range of parameters we expect for observations, the detector is not a major limitation. The liquid crystal variable retarders show the expected correlation between more rapid modulation (increased fraction of time spent switching) and an increase in statistical noise from demodulation.

This work was conducted by a Research Experience for Undergraduates (REU) position at the University of Hawai'i's Institute for Astronomy and funded by the NSF.

422.21 – **Established Designs For Advanced Ground Based Astronomical Telescopes In The 1-meter To 4-meter Domain**

Anthony B. Hull[1], J. Barentine[1], S. Legters[2]

[1]*L-3 Integrated Optical Systems: Tinsley,* [2]*L-3 Integrated Optical Systems: Brashear.*
9:00 AM - 2:00 PM

The same technology and analytic approaches that led to cost-effective unmitigated successes for the spaceborne Kepler and WISE telescopes are now being applied to meter-class to 4-meter-class ground telescopes, providing affordable solutions to ground astronomy, with advanced features as needed for the application. The range of optical and mechanical performance standards and features that can be supplied for ground astronomy shall be described. Both classical RC designs, as well as unobscured designs are well represented in the IOS design library, allowing heritage designs for both night time and day time operations, the latter even in the proximity of the sun. In addition to discussing this library of mature features, we will also describe a process for working with astronomers early in the definition process to provide the best-value solution. Solutions can include remote operation and astronomical data acquisition and transmission.

422.22 – **Challenges and Approach for Making the Top End Optical Assembly for the 4-meter Advanced Technology Solar Telescope**

Blaise Canzian[1], J. Barentine[1], T. Hull[1]

[1]*L-3 Communications/ IOS.*
9:00 AM - 2:00 PM

L-3 Integrated Optical Systems (IOS) Division has been selected by the National Solar Observatory (NSO) to make the Top End Optical Assembly (TEOA) for the 4-meter Advanced Technology Solar Telescope (ATST) to operate at Haleakala, Maui. ATST will perform to a very high optical performance level in a difficult thermal environment. The TEOA, containing the 0.65-meter silicon carbide secondary mirror and support, mirror thermal management system, mirror positioning and fast tip-tilt system, field stop with thermally managed heat dump, thermally managed Lyot stop, safety interlock and control system, and support frame, operates in the "hot spot" at the prime focus of the ATST and so presents special challenges. In this paper, we will describe the L-3 IOS technical approach to meet these challenges, including subsystems for opto-mechanical positioning, rejected and stray light control, wavefront tip-tilt compensation, and thermal management.

Key words: ATST, TEOA, L-3 IOS, thermal management, silicon carbide (SiC) mirrors, hexapods, solar astronomy

422.23 – **Astronomical Secondary Mirrors And Field Correctors: Special Challenges And Metrology Solutions Routinely Used At Brashear**

Francios Piche[1], G. Gardopee[1], A. Clarkson[1], T. Hull[1]

[1]*L-3 Communications Inc..*
9:00 AM - 2:00 PM

It has been said that the secondary mirror is the most difficult optic of an astronomical telescope. Much of this difficulty is associated with metrology of a convex mirror. With the advent of highly deterministic modern optical finishing machines delivering high process convergence rates, like those processes used at L-3 Integrated Optical Systems (IOS), the availability of high-quality metrology on convex optical surfaces is of greater importance to take full advantage of those new technological capabilities. Once the surface error map is determined, modern optical finishing machines, like those at L-3 Integrated Optical Systems (IOS), can readily make the correction, even on optics mounted in their deliverable cells. Due to IOS' innovative engineering coupled with our extensive experience with large, fast secondary mirrors, we have delivered exceptional mirrors on short schedules. We frequently address requirements where the optical figure must be controlled to a few nanometers in wavefront error, and associated metrology must address not only low spatial frequencies (LSF), but also mid spatial frequencies (MSF) and high spatial frequencies (HSF). Special tooling and techniques that control the accumulated error are described, and examples of control of all spatial frequencies presented. Methods are available at IOS to remove predicted mounting dimples whether measured in-situ with the optics mounted in its cell or predicted from a finite-element model of the mounted optic. We will also describe metrology methods for astronomical field correctors.

422.24 – **Lowell Observatory's Discovery Channel Telescope: Status, Key Science, and Opportunities**

Jeffrey C. Hall[1], S. E. Levine[1]

[1]*Lowell Obs..*
9:00 AM - 2:00 PM

On July 12, 2005 Lowell Observatory broke ground at the construction site of the 4.3-meter Discovery Channel Telescope (DCT) near Happy Jack, AZ, 40 miles southeast of Flagstaff and at an elevation of 7,800'. The facility is now nearly complete, with testing of the primary mirror and active optics well underway and testing at RC focus imminent. First light is expected by May 2012.

Lowell and its partners, Boston University and the University of Maryland, will use the DCT for a variety of projects including studies of star formation in dwarf galaxies, cometary nuclei and KBOs, activity variations of Sun-like stars, and ToO follow-up observations of GRBs. Discovery Communications will use results of projects carried out by Lowell and its partners in broadcast and online media, reaching 99 million households in the USA and over 1.5 billion subscribers worldwide. The first major feature on the making of the telescope is expected to air on Discovery in June 2012.

In this poster we describe the general capabilities of the telescope, first light instrument suite, and key science projects. We also seek an additional partner to join us, BU, and UMD and invite interested parties or institutions to visit this poster and the adjacent one, presented by DCT Commissioning Scientist Stephen Levine, for more information.

422.25 – **Lowell Observatory's Discovery Channel Telescope: Telescope and Systems Specifications and Commissioning Status**

Stephen Levine[1], J. C. Hall[1]

[1]*Lowell Observatory.*
9:00 AM - 2:00 PM

Lowell Observatory's 4.3-meter Discovery Channel Telescope is in the process of being commissioned now. The telescope is located 40 miles southeast of Flagstaff,AZ at an elevation of 7,800 feet. On sky testing of the major subsystems began in early fall 2011, with commissioning work leading up to first light in late spring of 2012. We present a review of the design specifications of the telescope and its major subsystems. This is followed by a discussion of the commissioning time-line, and current status and performance of the telescope, and optics (including the active optics support system for the primary mirror).

422.26 – **The Navy Optical Interferometer: Status, Science, Ongoing Development**

Gerard van Belle[1], D. J. Hutter[2], T. Armstrong[3], NOI Collaboration

[1]*Lowell Observatory,* [2]*US Naval Observatory,* [3]*Naval Research Laboratory.*
9:00 AM - 2:00 PM

The Navy Optical Interferometer (NOI) is a multi-aperture visible-light interferometer located on Anderson Mesa near Flagstaff, Arizona. NOI (formerly NPOI) is operated jointly by the Lowell Observatory, US Naval Observatory, and Naval Research Laboratory. The existing unique sub-milliarcsecond resolution capabilities of NOI are

being employed to image stellar surfaces, resolve stellar diameters and orbits, and probe circumstellar disk structures. Funded upgrades for NOI will add longer baselines and upgraded beam combination instrumentation, all of which are slated to become operational over the next 12 months; additional, larger apertures are also under consideration for the facility.

422.27 – **EXES: The Echelon-Cross-Echelle Spectrograph for SOFIA**

Curtis N. DeWitt[1], M. J. Richter[1], M. E. McKelvey[2], A. Seifahrt[3]

[1]*UC Davis,* [2]*NASA Ames Research Center,* [3]*University of Chicago, Department of Astronomy and Astrophysics.*

9:00 AM - 2:00 PM

The Echelon-cross-Echelle Spectrograph (EXES) is one of the first generation instruments for the Stratospheric Observatory for Infrared Astronomy (SOFIA). It operates at high, medium, and low spectral resolution in the wavelength region 4.5 to 28.3 microns using a 1024x1024 Si:As detector array. From SOFIA, the high spectral resolution mode (R ~ 100,000) will provide truly unique data given the improved atmospheric transmission. We present the current status of EXES including lab results with a new echelle grating, which enables the low resolution mode and a camera mode in addition to the previously available high and medium resolution modes.

422.28 – **A Rotating Polarized Source for Precise Calibration of Microwave Polarimeters**

Kristi J. Bradford[1], J. M. Kovac[1], A. G. Vieregg[1], Keck Array Team

[1]*Harvard University.*

9:00 AM - 2:00 PM

The Keck Array, a set of 5 microwave polarimeters located at the South Pole, is currently looking for the imprint of inflationary gravitational waves as B-mode polarization in the CMB. In order for the Keck Array to reach its sensitivity goal, the polarization orientation for each detector must be known to 0.1 degree precision and the polarization efficiency must be known to 0.5% precision. To perform this detector calibration, we designed and constructed a rotating polarized microwave source that can generate broadband radiation covering 100, 150 or 220 GHz bands, the observing frequencies of the Keck Array, in a broad beam with a precisely defined linear polarization and less than 0.5% cross-polar power. The source is capable of rotating a full 360 degrees and the absolute orientation angle of the source is known to <0.1 degrees. The source is affixed to a rotary stage with a stepper motor, and a high degree of linear polarization is achieved with a free-standing wire grid polarizer. The absolute orientation of the source is referenced to gravity using a built-in tilt meter. This new source allows the polarization response of each of the Keck Array's detectors to be measured, without which strong E-mode polarizations would appear as false B-mode patterns. Such false patterns would contaminate any real B-mode polarization signal or could be mistaken for cosmological birefringence.

422.29 – **The Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry (BLAST-Pol): Instrument and 2010 Science Campaign**

Natalie Gandilo[1], BLAST-Pol Collaboration

[1]*University of Toronto, Canada.*

9:00 AM - 2:00 PM

The Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry (BLAST-Pol) is a 1.8-m telescope that observes polarized dust emission with a resolution of ~1'. BLAST-Pol images the sky onto a focal plane that consists of 270 feed-horn coupled bolometers at 250, 350, and 500 microns. In January 2011, BLAST-Pol completed a successful 9.5-day flight over Antarctica. Eight science targets were observed, and a second flight is planned for December 2012. I will give an overview of the instrument performance during the first science campaign and present preliminary maps. BLAST-Pol maps will provide an excellent dataset for studying the role of magnetic fields in star formation.

422.30 – **Astronomical Performance Of The SCUBA-2 Camera On The JCMT**

Gary R. Davis[1], W. S. Holland[2], A. Chrysostomou[1], SCUBA-2 Team

[1]*Joint Astronomy Centre, United Kingdom,* [2]*UK Astronomy Technology Centre and Institute for Astronomy, University of Edinburgh, United Kingdom.*

9:00 AM - 2:00 PM

SCUBA-2 is an innovative 10,000-pixel camera operating at submillimetre wavelengths on the James Clerk Maxwell Telescope (JCMT) on Mauna Kea. It images the sky simultaneously in wavebands at 450 and 850 microns, and has a wide field-of-view of 43 square arcminutes. The detectors are superconducting transition-edge sensors, arranged in 4 sub-arrays at each waveband, and operating at temperatures close to 100mK to provide background-limited sensitivity. The readout consists of SQUID amplifiers in the focal plane with time-division multiplexing. In this paper we describe the electrical and thermal properties of the SCUBA-2 detector arrays as well as the early on-sky performance. The instrument is now in regular operation and a comprehensive submillimetre survey programme, the JCMT Legacy Survey, has commenced (see companion paper by Chrysostomou et al., session 40).

422.31 – **Stratopsheric Terrahertz Observatory Software Systems**

Thomas Shaw[1]

[1]*Oberlin College.*

9:00 AM - 2:00 PM

The Stratospheric Terrahertz Observatory (STO) is a complex balloon-based far-infrared telescope due to be launched December 2011. Software is an essential part of making the instrument flight-ready. Software is needed to receive and execute commands sent from the ground, to control the mechanical systems, to handle pointing, to monitor instrument status, to correlate observations with calibration and pointing data, and finally to process the data. This poster will give an overview of all of the flight software systems, and will go into detail on a few of them, noting potential pitfalls and ways to avoid them. Depending on the launch date, it may include data taken during the flight. Areas of focus will most likely include data acquisition and processing.

422.32 – **Terahertz Ballooning: STO And GUSSTO**

Christopher L. Martin[1], Stratospheric TeraHertz Observatory (STO) Team, Gal/Xgal U/LDB Spectroscopic/Stratospheric THz Observatory (GUSSTO) Team

[1]*Oberlin College.*

9:00 AM - 2:00 PM

With a long duration balloon launch from Antarctica in December 2011, the Stratospheric TeraHertz Observatory (STO) is expected to have just completed its maiden science flight by the time of the AAS meeting. Our team will present some of the first glimpses from this mission to map the interstellar medium (ISM) in [CII], [NII], and [CI] at high spectral and spatial resolution.

Additionally, NASA recently announced the missions that will begin Phase A studies under the Explorer Program, which included the Gal/Xgal U/LDB Spectroscopic/Stratospheric THz Observatory (GUSSTO). GUSSTO is a balloon-borne, 1 m off-axis telescope that will survey ~300 square degrees of the Milky Way and Large Magellanic Cloud (LMC) in 3 important interstellar ines: [CII], [OI], and [NII] at 158, 63, and 205 microns, respectively. With these lines, GUSSTO will map the structure, dynamics, energy balance, pressure, and evolution of the ISM. Our poster will explain the concepts and plans for this exciting mission.

422.33 – **The Low Frequency All Sky Monitor for the Study of Radio Transients: Array Configuration and Sensitivity**

Rossina B. Miller[1], F. A. Jenet[1], B. Hicks[2], N. E. Kassim[2], P. S. Ray[2], G. B. Taylor[3]

[1]*University of Texas at Brownsville,* [2]*Naval Research Laboratory,* [3]*University of New Mexico.*

9:00 AM - 2:00 PM

The forthcoming Low Frequency All Sky Monitor (LoFASM), will be an array of dipoles working between 10-88 MHz adapted from the Long Wavelength Array (LWA) design. This array will offer significant advantages over other projects for the study of radio transients, but its effectiveness will depend on the geometric details of the array. This poster presents the results of theoretical sensitivity calculations for a single 12 antenna array. An optimal configuration was found that can effectively block terrestrial signals incident from the horizon at certain "resonant" frequencies. This configuration will allow LoFASM to operate in regions with relatively high radio frequency interference. We also discuss possible transient sources that could be studied by this instrument.

422.34 – **Low Frequencies in New Mexico: The EVLA Low Band Upgrade and The Long Wavelength Array Station One**

Namir E. Kassim[1], T. E. Clarke[1], B. C. Hicks[1], P. S. Ray[1], S. Durand[2], P. Harden[2], L. Kogan[2], C. Kutz[2], F. Owen[2], R. A. Perley[2], M. Pospieszalski[2], Long Wavelength Array Consortium

[1]*NRL,* [2]*NRAO.*

9:00 AM - 2:00 PM

We present a description and update of the Expanded Very Large Array (EVLA) Low Band project, an initiative to equip the National Radio Astronomy Observatory (NRAO) EVLA (http://www.aoc.nrao.edu/evla/) with broadband low frequency receivers which cover the spectrum between 50 and 436 MHz. The EVLA system will initially access the 68 to 86 MHz and 230 to 436 MHz sub-bands by working with the existing 74 and 330 MHz feeds, respectively. The bandwidth at 74 MHz will increase by more than an order of magnitude while the 330 MHz bandwidth increases by approximately a factor of 6. The improved bandwidth and system temperature, coupled with the power of the EVLA WIDAR correlator, will significantly enhance the performance in both bands compared to past VLA capabilities.

We also present an update on commissioning of the first station of the Long Wavelength Array (LWA: http://lwa.unm.edu), a new digitally steerable radio telescope designed to operate from 10 to 88 MHz. The full LWA instrument will consist of over 50 phased array "stations" which are distributed over a roughly 400 km region in the state of New Mexico. Each station will consist of 256 pairs of dipole-based antennas. The signals can be formed into 4 beams with separate frequency and sky pointings. The output beams are transported to a central location for high-resolution aperture synthesis imaging with

mJy sensitivities and arcsecond resolution. We will show early examples of observations with the first complete LWA station, called LWA1, located near the core of the EVLA. The potential to combine low frequency signals from early LWA stations with the new EVLA Low Band system is also being explored.

422.35 – **The Low Frequency All Sky Monitor for the Study of Radio Transients: Prototype Hardware Development**

Jesus Rivera[1], A. J. Ford[1], F. A. Jenet[1], K. Stovall[1], S. C. Cohen[1], L. Dartez[1], A. Garcia Jr.[1], J. Hinojosa[1], C. Longoria[1], G. Lunsford[1], A. Mata[1], R. B. Miller[1], J. S. Reser[1], B. C. Hicks[2], N. E. Kassim[2], P. S. Ray[2], G. B. Taylor[3]

[1]University of Texas at Brownsville, [2]U.S. Naval Research Lab, [3]University of New Mexico.

9:00 AM - 2:00 PM

In radio astronomy, the low frequency band (< 88 MHz) is one of the least explored regions of the electromagnetic spectrum. The Low Frequency All Sky Monitor (LoFASM), built from technology designed for the Long Wavelength Array (LWA), will be dedicated to the continuous, long-term monitoring of this band. The primary science goal of this project will be the study of radio transients, bursts of radio radiation that can last for a wide range of time scales from micro-seconds to several days. The full LoFASM project will consist of three independent antenna arrays, or "stations," separated by several thousand kilometers, observing coincident parts of the sky, allowing fast discrimination of local and astronomical signals. The sensitivity and geographical distribution of the LoFASM antennas will offer significant advantages for the study of radio transients compared to previous and ongoing programs. This poster describes the analog and digital hardware implemented in the prototype system which has been developed by undergraduate students working at UTB's Center for Advanced Radio Astronomy.

422.36 – **The AARTFAAC Project: Searching for Radio Transient Signals with LOFAR**

Yvette Cendes[1], AARTFAAC Project Team

[1]University of Amsterdam, Netherlands.

9:00 AM - 2:00 PM

The LOFAR project will provide an unparalleled new opportunity to search for transient radio signals from extreme phenomena beginning in 2011. The AARTFAAC project will hunt for such rare extreme transients with plans to document several examples of each transient, eventually expanding the project into a 24/7 all-sky monitor. We expect AARTFAAC to provide us with an unprecedented picture of the radio transient sky and shed new light on these exotic signals.

422.37 – **The Expanded Very Large Array: Exploring the Microjansky Sky**

Michael P. Rupen[1], EVLA Commissioning Team

[1]NRAO.

9:00 AM - 2:00 PM

The Expanded Very Large Array (EVLA) began operations last year as one of the premier radio telescopes in the world. Building on the infrastructure of the Very Large Array (VLA) the EVLA offers order-of-magnitude improvements in sensitivity and spectral capability, as well as continuous frequency coverage from 1 to 50 GHz. The project is on track for completion by the end of 2012, but the EVLA is already conducting shared-risk scientific observations. Here I summarize the rapidly expanding capabilities of the EVLA, and provide some examples of the scientific results that are already appearing.

422.38 – **Accurately Measuring the Spillover of a Radio Telescope**

Ronald J. Maddalena[1], M. E. Mattox[2]

[1]NRAO, [2]Linkhorne Middle School.

9:00 AM - 2:00 PM

Spillover, the fraction of power received by a radio telescope that originates from the ground, contributes to the system temperature (Tsys) and, thus, degrades slightly the performance of the telescope. Some methods of calibrating data from radio telescopes require accurate knowledge of the spillover contribution. Since the amount of power received from the ground changes with elevation, so does the contribution to Tsys. In most cases, there is no way to distinguish empirically between the elevation-dependent contribution to Tsys from spillover and from the Earth's atmosphere. Thus, determining spillover is usually done from theoretical models of the telescope's optics. By using recently-constructed, accurate models of the contribution to Tsys from the Earth's atmosphere, we have derived a method whereby one can determine to an accuracy of less than a percent the elevation dependence of the contribution of spillover to Tsys. The measured spillover can then be compared to the theoretical models. We have applied this technique to the Green Bank Telescope, a challenging telescope since it has an extremely low spillover contribution, and have found that the measured and theoretical spillovers are in disagreement.

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423 – Science Highlights from NASA's Astrophysics Data Analysis Program

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

423.01 – **Charge Exchange Models with AtomDB v2.0**

Randall K. Smith[1], A. Foster[1], N. Brickhouse[1]

[1]Smithsonian Astrophysical Observatory.

9:00 AM - 2:00 PM

Charge Exchange (CX) X-ray emission from geocoronal and heliospheric sources is no longer in doubt, and there are hints of its prevalence elsewhere in the Universe. However, there does not exist a general model of what an astrophysical CX spectrum might like look, even in an approximate way. We present an enhanced version of the basic method described by Wegmann et al. (1998), which uses a hydrogenic model for the CX cross section into the highly-excited state. The atomic structure and radiative transitions data available in the AtomDB is used to determine the spectrum emitted as the ion stabilizes by radiative decay. One uncertainty in the process is the angular momentum of the exchanged electron. This will be addressed by providing three options for the model: (1) distributing the electrons by the relative statistical weight of each level, (2) assuming the angular momentum of the electron is zero, or (3) assuming the angular momentum of the electron is the largest possible value for the ion. Sample X-ray spectra will be shown for typical situations.

423.02 – **The Resolved Star Formation Rate in the Nearby Fireworks Galaxy: NGC6946**

Rafael T. Eufrasio[1], E. Dwek[2], R. Arendt[3], D. Fixsen[3]

[1]NASA Goddard Space Flight Center / The Catholic University of America, [2]NASA Goddard Space Flight Center, [3]NASA Goddard Space Flight Center / University of Maryland in Baltimore County.

9:00 AM - 2:00 PM

We derive the spatially resolved star formation rate (SFR) for the face-on nearby galaxy NGC6946 by decomposing the radio emission from this galaxy into its thermal and non-thermal components. The decomposition utilized five radio maps from 3.5 cm to 22 cm that were convolved to a common angular resolution of 15 arcsec (500 pc). The derived free-free emission correlates well with the extinction corrected Hα emission. Model HII regions were used to derive the extinction-free number of ionizing photons and consequently the SFR.

423.03 – **Analyzing the SEDs of Deeply Embedded Protostars. The Example of IRAS 05345+3157.**

Randolf Klein[1], K. I. Lee[2], L. W. Looney[2], T. Henning[3]

[1]SOFIA - USRA, [2]UIUC, [3]MPIA Heidelberg, Germany.

9:00 AM - 2:00 PM

Massive stars play a major role in our and other Galaxies despite their low numbers, but it is not understood how they form. Intensive modeling has allowed us to better understand how massive stars can accrete despite their high luminosities, but the discussion is on-going on how the mass of the star-forming cloud is assembled onto the star.

Two protostars of intermediate mass have been identified in the star-forming region around IRAS 05345+3157. Observations with Spitzer and CARMA, combined with literature data, allowed us to construct the complete spectral energy distribution (SED) for two dense molecular cores in that region. We fit the SED with a radiative transfer (RT) model using the on-line model grid by Robitaille et al.(2007). The SED fit allows us determine the protostar's and its envelope's properties. A detailed analysis is performed to determine which parameters are well constrained by the SED which and which are not. Adding near infrared (NIR) and interferometric observations, a comprehensive picture of the star-forming region is created. The synthesis of the information on the region around IRAS 05345+3157 allows us understand the star formation history of the region and its current status.

This study serves as a pilot study to extend the SED fitting and parameter analysis to 168 candidates for massive embedded protostars selected from millimeter surveys of massive star-forming regions. These clumps are selected to be in a very early stage of their evolution. This will provide the theoretical underpinning to understand the SEDs and their evolution. The goal is to track observable and physical quantities using SEDs through the early stages of massive star formation to classify the stages and understand their evolution.

423.04 – **Multi-component SED Fitting Of AGN Host Galaxies**

Seth H. Cohen[1], R. E. Ryan[2], R. A. Windhorst[1], N. A. Grogin[2], N. P. Hathi[3], A. N. Straughn[4], M. R. Mechtley[1], A. M. Koekemoer[2], R. W. O'Connell[5], WFC3 SOC

[1]*Arizona State University,* [2]*STScI,* [3]*OCIW,* [4]*NASA/GSFC,* [5]*University of Virginia.*
9:00 AM - 2:00 PM

We present results of a multi-wavelength analysis of the stellar populations of AGN host galaxies selected from the GOODS-South field. In order to account for an unknown fraction of AGN light, we add a simple power-law with a variable slope to the stellar population synthesis templates of Bruzual and Charlot. In this way, we can simultaneously constrain several properties of the AGN and its host, namely stellar mass, stellar population age, and AGN fraction as a function of wavelength. The method is also applied to the subset of the data which was covered by HST/WFC3 with the UVIS and IR channels as part of the WFC3 Early Release Science (ERS) observations. The sample of objects selected to have significant non-stellar components is compared to samples of AGN selected by other means (i.e., X-rays, radio emission, mid-IR flux, ground-based spectra) in this well-studied field.

This work 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 #11359 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. Most of the early work was funded by NASA's Astrophysics Data Analysis Program (ADAP) NNX 07AH58G.

424 – Large Programs: Hobby-Eberly Telescope Dark Energy Experiment

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

424.01 – **HETDEX: Overview of the Hobby-Eberly Telescope Dark Energy Experiment and Instrumentation**

Gary J. Hill[1], K. Gebhardt[1], N. Drory[2], D. DePoy[3], E. Komatsu[1], R. Bender[4], D. Schneider[5], M. Fabricius[4], H. Lee[1], S. Tuttle[1], J. Marshall[3], A. Kelz[6], M. Roth[6], M. Cornell[1], HETDEX Collaboration

[1]*Univ. of Texas, Austin,* [2]*Instituto de Astronomia, UNAM, Mexico,* [3]*Texas A&M University,* [4]*MPE, Germany,* [5]*Pennsylvania State University,* [6]*AIP, Germany.*
9:00 AM - 2:00 PM

The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a blind spectroscopic survey to map the evolution of dark energy using Lyman-alpha emitting galaxies as tracers. HETDEX comprises a major upgrade of the HET, deployment of the massively replicated integral field spectrograph, VIRUS, and the execution of a multi-year blind spectroscopic survey. VIRUS, consists of 75 IFUs distributed across the 22-arcmin field of the upgraded 9.2-m HET. Each 50x50 sq. arcsec IFU is made up of 448 1.5-arcsec fibers, and feeds a pair of spectrographs with a fixed bandpass of 350-550 nm and resolving power R~700. Each exposure gathers 33,600 spectra. Observing 20 minutes per field, we reach a line flux limit of 3.5e-17 ergs-sec-1-cm-2 and mAB~22. The baseline survey will deliver spectra of 0.8M LAEs in a 9 cubic Gpc volume with $1.9 < z < 3.5$, and 1M [OII] emitters with $z < 0.48$. In addition, the survey will cover 0.4M other galaxies, 0.25M stars, 2000 galaxy clusters, 7000 QSOs with $z < 3.5$, and 20,000 NVSS radio sources. The main survey area of 42x7 sq. deg. is centered at 13hr, +53deg. Within that 300 sq. deg. region we cover 1/4.5 with fibers; thus 60 sq. deg. of sky have spectra. Initial observations will be conducted from Spring 2013 through Spring 2015. We present an overview of the project, including instrumentation and details of the planned surveys.

424.02 – **HETDEX: Measuring Dark Energy at High Redshift**

Karl Gebhardt[1], G. Hill[1], E. Komatsu[1], N. Drory[2], D. DePoy[3], R. Ciardullo[4], C. Gronwall[4], M. Fabricius[5], L. Wisotzki[6], HETDEX Collaboration

[1]*Univ. of Texas at Austin,* [2]*Instituto de Astronomia UNAM, Mexico,* [3]*Texas A&M University,* [4]*Pennsylvania State University,* [5]*Max-Planck-Institut fuer Extraterrestrische Physik, Germany,* [6]*Astrophysikalisches Institut Potsdam, Germany.*
9:00 AM - 2:00 PM

The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a blind spectroscopic survey to map the evolution of dark energy using Lyman-alpha emitting galaxies as tracers. The survey instrument, VIRUS, consists of 75 IFUs distributed across the 22-arcmin field of the upgraded 9.2-m HET. Each 50x50 sq. arcsec IFU is made up of 448 1.5-arcsec fibers, and feeds a pair of spectrographs with a fixed bandpass of 350-550 nm and resolving power R~700. Each exposure gathers 33,600 spectra. The baseline survey will deliver spectra of 0.8M LAEs in a 9 cubic Gpc volume with $1.9 < z < 3.5$, and 1M [OII] emitters with $z < 0.48$. We expect to measure both the Hubble parameter and angular diameter distance to better than 1%. HETDEX will provide a unique window on the evolution of dark energy.

424.03 – **HETDEX: Evolution and Drivers of Cosmic Star Formation Over 12 Billion Years**

Shardha Jogee[1], K. Gebhardt[1], R. Ciardullo[2], C. Gronwall[2], S. Finkelstein[1], C. Papovich[3], T. Weinzirl[1], M. Song[1], K. Finkelstein[1], N. Evans[1], N. Drory[4], E. Mentuch[1], HETDEX Team

[1]*Univ. of Texas, at Austin,* [2]*Penn State University,* [3]*Texas A&M University,* [4]*Universidad Nacional Autonoma de Mexico (UNAM), Mexico.*
9:00 AM - 2:00 PM

Starting in 2012, the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) survey will map 300 square degrees of the sky in blind spectroscopic mode using the VIRUS IFU. Over the last 5 Gyr out to $z<0.5$, HETDEX will enable us to map the evolution of the cosmic star formation rate (SFR) density in different environments, the relation between SFR and stellar mass, and the factors driving star formation, including the contribution of galaxy mergers. Over the 28 square degree area, which will have HETDEX spectra, along with deep optical (DES) and near-infrared (Spitzer) images, at $z<0.5$ we expect to measure stellar masses down to 10^9 solar masses, detect over 60,000 [O~II] emitters, cross-correlate different tracers of SF, and trace SFR down to 0.5 solar masses per year. This will allow us to overcome numerous limitations of earlier studies, such as small number statistics, the use of SF tracers detected in only the most actively star-forming systems, and the predominant use of photometric redshifts. At higher redshifts $1.9<z<3.5$, the 200,000 Lyman alpha emitters directly detected by HETDEX over the same region, combined with the halo mass inferred from clustering statistics, and the wide range of environments (field, groups, and proto-clusters) probed by our large comoving volume (0.2 Gpc^3), will allow us to directly study how star formation proceeds in different halo masses and environments over the epoch of peak cosmic star formation and AGN activity.

424.04 – **HETDEX: Constraining Inflation With Primordial Non-Gaussianity**

Donghui Jeong[1], E. Komatsu[2], G. J. Hill[2], K. Gebhardt[2], HETDEX Collaboration

[1]*Johns Hopkins University,* [2]*Univ. of Texas, Austin.*
9:00 AM - 2:00 PM

Hobby-Eberly Dark Energy Experiment (HETDEX) will yield about 800,000 blindly-detected spectra of distant (z=1.9-3.5) galaxies. By analyzing the power spectrum and the bispectrum of HETDEX galaxies, we can measure the primordial non-Gaussianity. This will enable us to constrain the physics of the early universe, because detecting the local type primordial non-Gaussianity will rule out all single field inflation models regardless of their details. In this poster, we present constraints on inflationary models expected from the HETDEX 3-year survey.

424.05 – **HETDEX: AGN Statistics**

Andreas Schulze[1], L. Wisotzki[2], L. Hao[3], HETDEX Collaboration

[1]*Kavli Institute for Astronomy and Astrophysics, China,* [2]*Leibniz Institute for Astrophysics, Germany,* [3]*Shanghai Astronomical Observatory, China.*
9:00 AM - 2:00 PM

HETDEX will provide the largest well-defined sample of AGN without any preselection applied so far. It will detect more than 10000 AGN up to z=3.5 and down to g~22-24 mag, highly valuable for statistical investigations. In particular, it will probe the peak of the AGN space density between z=2-3 with high completeness and statistical accuracy, a range where colour selected samples have serious problems to discriminate AGN from the stellar locus. Thus the HETDEX AGN sample will provide much better constraints on the faint end of the AGN luminosity function, especially between z=2 and z=3.5, probing several magnitudes deeper than the SDSS.

The spectral information will allow the estimation of black hole masses and Eddington ratios for the sample up to z~2.5. This will enable the determination of the active black hole mass function and the distribution function of Eddington ratios. Furthermore, HETDEX will offer a unique data set for AGN-galaxy clustering studies, as in the redshift range $1.9<z<3.5$ it will include a large number of AGN and galaxies in the same volume. This will enable a better understanding of AGN, their environments and black hole-galaxy coevolution.

424.06 – **HETDEX: AGN Selections and Their Host Galaxy Studies**

Lei Hao[1], A. Schulze[2], HETDEX Collaboration

[1]*Shanghai Astronomical Observatory, China,* [2]*Leibniz-Institut fur Astrophysik Postdam, Germany.*
9:00 AM - 2:00 PM

We describe in detail the selection methods of detecting various types of AGNs both at high redshift of z~2-4 and at the center of nearby galaxies from the HETDEX survey. We estimate the completeness of high-z AGNs via dedicated simulations. We investigate the cross-identifications of the HETDEX AGN sample and all sky surveys at other wavelengths, and discuss the science implications we can achieve on host galaxy properties of these faint AGNs.

424.07 – **HETDEX: A Magnitude-limited Spectroscopic Sample Of Stars In The Galaxy Down To V~20**

Carlos Allende-Prieto[1], M. Shetrone[2], S. C. Odewahn[2], G. Benedict[2], B. G. Castanheira[3], R. de Jong[4], D. L. Lambert[2], P. J. MacQueen[2], J. L. Marshall[5], B. E. McArthur[2], C. Sneden[6], HETDEX collaboration

[1]Instituto de Astrofisica de Canarias, Spain, [2]McDonald Observatory, [3]Universidade Federal do Rio Grande do Sul, Brazil, [4]Leibniz-Institut fur Astrophysik Potsdam, Germany, [5]Texas A & M University, [6]University of Texas at Austin.

9:00 AM - 2:00 PM

Spectroscopic surveys of stars in the Milky Way are growing rapidly in size and scope, with the ambitious goals of unravelling the Galaxy's formation and evolution, and finding out whether our galaxy fits the current paradigm of hierarchical galaxy formation driven by cold dark matter. These surveys follow target selection algorithms aimed at extracting the most information out of a coarse sampling of the stars in the Galaxy, and as result they are seriously biased. HETDEX will be the first project to change that -- obtaining low-resolution (R~750) spectra covering 350-550 nm that will render radial velocities and overall metallicity for a flux-limited sample of > 100,000 stars down to V~20 over 60 square degrees. Questions that we hope to address include: 1) the incidence of gross chemical peculiarities, 2) the metallicity distributions of the main Galactic components, and 3) the frequency of cold substructure over a range of scales. We show simulated data and explore the performances of our preliminary data analysis software.

424.08 – **White Dwarf Stars in the HET Dark Energy Experiment**

Barbara Castanheira[1], D. Winget[1], K. Gebhardt[1], C. Allende Prieto[2], M. Shetrone[1], S. Odewahn[1], M. H. Montgomery[1]

[1]University of Texas, [2]Instituto de Astrofisica de Canarias, Spain.

9:00 AM - 2:00 PM

In this poster, we present the project that will survey all white dwarf stars observed in the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) and the Visible Integral-field Replicable Unit Spectrograph (VIRUS) observations in parallel mode. The final product will be a unique magnitude-limited catalog of as many as 10,000 stars. Since we will use data from an Integral-field Units, our survey will be free of the selection biases that plagued preceding surveys, e.g. the Sloan Digital Sky Survey (SDSS). The critical advantages of our program are our ability to produce a white dwarf luminosity function five magnitudes fainter than the one derived from the Palomar-Green survey and with a similar number of faint stars as the one from SDSS. Our project will help to derive a more precise age of the Galactic disk, and will provide fundamental information about the white dwarf population and the star formation history of the Milky Way, impacting the white dwarf field and many other fields of astronomy.

424.09 – **SHELA: The Spitzer-HETDEX Exploratory Large Area Survey**

Casey J. Papovich[1], K. Gebhardt[2], P. Behroozi[3], R. Bender[4], G. A. Blanc[5], R. Ciardullo[6], D. DePoy[1], R. de Jong[7], N. Drory[8], N. Evans[2], M. Fabricius[4], S. Finkelstein[2], E. Gawiser[9], J. Greene[10], C. Gronwall[6], G. Hill[2], U. Hopp[11], S. Jogee[2], M. Lacy[12], M. Landriau[4], J. Marshall[1], S. Tuttle[2], R. Somerville[9], M. Steinmetz[7], N. Suntzeff[1], K. Tran[1], R. Wechsler[3], L. Wisotzki[7]

[1]Texas A&M University, [2]University of Texas-Austin, [3]Stanford University, [4]MPE, Germany, [5]Carnegie Observatories, [6]Penn State University, [7]AIP, Germany, [8]Universidad Nacional Autonoma de Mexico (UNAM), Mexico, [9]Rutgers University, [10]Princeton University, [11]Munich University, Germany, [12]NRAO.

9:00 AM - 2:00 PM

We present an overview of our Spitzer Exploratory survey to obtain IRAC imaging in a 28 sq deg field with deep optical imaging lying within the Hobby−Eberly Telescope Dark Energy Experiment (HETDEX) Survey. Our goal is to explore the relationship between galaxy stellar mass, dark-matter halo mass, and environment during the important cosmic epoch (redshifts 2<z<3) where the star formation and AGN activity in galaxies peak. The combination of HETDEX spectroscopy and deep IRAC and optical imaging in our program will provide a uniquely powerful dataset enabling these goals. Working in blind spectroscopic mode, HETDEX will obtain redshifts in this field for approximately 200,000 galaxies and map out the cosmic web at redshifts 1.9<z<3.5, over a large comoving volume of approximately 0.2 Gpc^3, competitive with SDSS at low redshifts.This volume spans a broad range of environments within the cosmic web, representative of field, groups, and proto−clusters. The IRAC data will provide the key missing ingredient by allowing us to measure galaxy stellar masses down to values well below the characteristic mass of the stellar mass function at these redshifts. By combining the IRAC data with the halo mass and local density (environment) measured from clustering statistics in the spectroscopic and associated trained photometric dataset, we will obtain a detailed view of how galaxies grow their stellar mass within different dark matter halos and as a function of environment. Ultimately, this study will advance our understanding of the physical processes that drive the formation of stars in galaxies and the build up of stellar mass over cosmic time. In the spirit of Exploratory programs, SHELA will enable a broad range of scientific explorations beyond our immediate goals by delivering all science products (images, catalogs, spectra, and redshifts) to the public.

424.10 – **HETDEX: Cosmology with High-z Galaxy Survey**

Eiichiro Komatsu[1], G. J. Hill[1], K. Gebhardt[1], D. Jeong[2], M. Shoji[1], C. Chiang[1], HETDEX Collaboration

[1]Univ. of Texas, Austin, [2]Johns Hopkins University.

9:00 AM - 2:00 PM

Hobby-Eberly Dark Energy Experiment (HETDEX) will yield about 800,000 blindly-detected spectra of distant (z=1.9-3.5) galaxies, providing an unprecedented opportunity to measure the large-scale structure of the universe in a high-redshift universe. This unique dataset is expected to improve our understanding of the physics of inflation, the nature of dark matter and dark energy, and the properties of neutrinos. In this poster, we present cosmological constraints expected from the HETDEX 3-year survey.

424.11 – **HETDEX: The Physical Properties of [O II] Emitters**

Robin Ciardullo[1], C. Gronwall[1], G. Blanc[2], K. Gebhardt[3], S. Jogee[3], HETDEX Collaboration

[1]Penn State Univ., [2]Carnegie Observatories, [3]Univ. of Texas.

9:00 AM - 2:00 PM

Beginning in Fall 2012, the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) will map out 300 square degrees of sky via a blind integral-field spectroscopic survey. While the main goal of the project is to measure the power spectrum of ~ 800,000 Lyα emitters between $1.9 < z < 3.5$, the survey will also identify ~ 1,000,000 [O II] emitting galaxies with $z < 0.5$. Together, these data will provide an unprecedented view of the emission-line universe and allow us to not only examine the history star formation, but to study the properties of star-forming galaxies as a function of environment.

To prepare for HETDEX, a 3 year pilot survey was undertaken with a proto-type integral-field spectrograph (VIRUS-P) on the McDonald 2.7-m telescope. This program, which tested the HETDEX instrumentation, data reduction, target properties, observing procedures, and ancillary data requirements, produced R=800 spectra between 350 nm and 580 nm for 169 square arcmin of sky in the COSMOS, GOODS-N, MUNICS-S2, and XMM-LSS fields. The survey found 397 emission-line objects, including 104 Lyα emitters between $1.9 < z < 3.8$ and 284 [O II] galaxies with $z < 0.56$. We present the properties of the [O II] emitters found in this survey, and detail their line strengths, internal extinction, and emission-line luminosity function. We use these data to show that over the past ~ 5 Gyr, star-formation in the universe has decreased linearly, in both in an absolute and relative sense. We compare the star formation rates measured via [O II] fluxes to those determined via the rest-frame ultraviolet, explore the extinction corrections for our sample, and discuss the implications of our work for the main HETDEX survey.

424.12 – **HETDEX: The Physical Properties of Lyman-alpha Emitters**

Caryl Gronwall[1], G. Blanc[2], R. Ciardullo[1], S. Finkelstein[3], E. Gawiser[4], K. Gebhardt[3], HETDEX Collaboration

[1]Penn State Univ., [2]Carnegie Observatories, [3]Univ. of Texas, [4]Rutgers Univ..

9:00 AM - 2:00 PM

Beginning in Fall 2012, the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) will map out 300 square degrees via a blind integral-field spectroscopic survey which will detect ~800,000 Lyman-alpha emitters (LAEs) at $1.9 < z < 3.5$. The goal of HETDEX is to explore the expansion history of the universe via the LAE power spectrum, but these emission-line sources are also important probes of galaxy evolution. LAEs are observed "in the act" of formation with low mass, little dust, very young ages, and a two-dimensional clustering scale-length that implies that they are the progenitors of today's Milky Way type galaxies. The unprecedented size of the HETDEX survey will allow us to explore the 3-D clustering of these objects and to measure their halo masses as a function of redshift. We will also be able to explore the physical properties of LAEs over a wide range of environments, and study how their luminosity functions, equivalent width distributions, and star formation rates change with galaxy density and redshift.

In preparation for HETDEX, we undertook a 3 year pilot survey to test the feasibility of the experiment and design an optimal observing strategy. These observations were performed with a proto-type HETDEX spectrograph (VIRUS-P) on the McDonald 2.7-m telescope, and covered Ly-alpha in the redshift range $1.9 < z < 3.8$. This survey discovered 104 Ly-alpha emitting galaxies in 169 sq. arcmin of sky, and reached objects with Ly-alpha line luminosities as faint as 3×10^{42} ergs/s. We will present the Ly-alpha luminosity function, equivalent width distributions, and star formation rates measured for this sample and discuss the implications of the pilot survey results for HETDEX.

424.13 – **HETDEX: Evolution of Lyman Alpha Emitters**

Guillermo A. Blanc[1], K. Gebhardt[2], G. J. Hill[2], C. Gronwall[3], R. Ciardullo[3], S.

Finkelstein[2], E. Gawiser[4], HETDEX Collaboration

[1]Carnegie Observatories, [2]Univeristy of Texas at Austin, [3]Penn State University, [4]Rutgers University.

9:00 AM - 2:00 PM

The Hobby Eberly Telescope Dark Energy Experiment (HETDEX) will produce a sample of ~800,000 Lyman Alpha Emitters (LAEs) over the 1.9<z<3.5 range. This epoch marks a peak in star formation activity over the whole universe, and is therefore of prime importance to understand the assembly of galaxies. The HETDEX LAE sample will allow us to probe the evolution of these young star-forming systems with unprecedented detail. We present results from the HETDEX Pilot Survey, conducted with the prototype instrument VIRUS-P, regarding the redshift evolution of different physical properties of LAEs, including their number density, dust content, and Lyman Alpha photon escape fraction. Our results show a strong evolution in the Lyman Alpha escape fraction with redshift, most likely associated with the buildup of dust in the ISM. Dust is shown to be the main parameter setting the escape of Lyman Alpha photons. The observed relation between E(B-V) and the escape fraction indicates that radiative transfer effects in LAEs promote the escape of Lyman Alpha photons, but only up to the point of them suffering similar amounts of extinction as continuum photons. Enhancement of the Lyman Alpha EW (e.g. due to the presence of a clumpy medium) seems not to be a common process in these objects. We also discuss the potential of the full HETDEX sample to study the evolution of LAE properties.

424.14 – **HETDEX: Two-dimensional Galaxy Power Spectrum**

Chi-Ting Chiang[1], E. Komatsu[1], D. Jeong[2], G. J. Hill[1], K. Gebhardt[1], HETDEX Collaboration

[1]The University of Texas at Austin, [2]Johns Hopkins University.

9:00 AM - 2:00 PM

Hobby-Eberly Dark Energy Experiment (HETDEX) will gather the spectra from roughly 800,000 distant galaxies at z=1.9-3.5. The two-dimensional galaxy power spectrum contains much more information beyond the angular averaged power spectrum. By analyzing the angular dependence of the 2-d power spectrum, we can separately measure the angular diameter distance and Hubble constant as well as the growth rate of cosmic structures. Such measurement will further improve our understanding on the nature of dark energy, and it will also enable us to test the general theory of relativity on cosmological scales. In this poster, we will present the expected 2-d power spectrum from HETDEX and the cosmological constraints.

424.15 – **HETDEX: Nearby Galaxies**

Niv Drory[1], K. Gebhardt[2], S. Jogee[2], M. Fabricius[3], J. Greene[4], HETDEX Collaboration

[1]Universidad Nacional Autonoma De Mexico, Mexico, [2]University of Texas, [3]Max-Planck Institute for Extraterrestrial Physics, Germany, [4]Princeton University.

9:00 AM - 2:00 PM

The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a blind spectroscopic survey using the VIRUS instrument. VIRUS consists of 75 IFUs distributed across the 22-arcmin field of the upgraded 9.2-m HET. Each 50x50 arcsec IFU is made up of 448 1.5-arcsec fibers, and feeds a pair of spectrographs with a fixed bandpass of 350-550 nm and resolving power R~700. The IFUs have a fill-factor of 1/3 which will be filled-in by dithering. We cover 1/4.5 of our 300-square-degree main survey area with fibers. We reach m_AB~22.6 (21.5,20.7) at S/N 3 (5,10) per resolution element. With these limits, g~17 spiral galaxies will have S/N>3 per resolution element per fiber in the continuum to ~2 effective radii, and emission line spectra to at least their optical radius. HETDEX will spatially resolve ~4000 local galaxies to that limit without any pre-selection; an additional ~9000 local galaxies will have spatially resolved spectroscopy beyond that limit. At g~19 we still obtain integrated galaxy spectra at S/N~10 per resolution element in the continuum. These spatially resolved absorption and emission spectra provide information on star formation, the state of the IGM, and stellar populations, as well as rotation curves for an unbiased galaxy sample unprecedented in size. Since a wealth of information about a galaxy's formation history is encoded in gradients across the galaxy, moving from single-fiber (SDSS-like) spectra to large samples of spatially resolved galaxy spectroscopy opens a new parameter space for future studies of galaxy formation.

424.16 – **HETDEX: Probing the Chemical Evolution of the Universe with Lyman Alpha Emitting Galaxies**

Steven L. Finkelstein[1], G. J. Hill[1], K. Gebhardt[1], G. Blanc[2], N. Drory[3], HETDEX Collaboration

[1]University of Texas, [2]Carnegie Observatories, [3]Universidad Nacional Autonoma de Mexico, Mexico.

9:00 AM - 2:00 PM

The Hobby Eberly Telescope Dark Energy Experiment (HETDEX) will discover ~0.8 million Lyman alpha emitting galaxies (LAEs) at $1.9 < z < 3.5$ over 300 square degrees beginning in Fall 2012. This unprecedentedly large volume probed will allow the discovery of large samples of bright LAEs, enabling follow-up science which cannot be done for the bulk of the LAE population, as they form the faint end of the galaxy luminosity function. Combining the HETDEX sample with the new generation of multi-object near-infrared (NIR) spectrographs will allow direct measurements of LAE physical properties, which are of interest as LAEs appear similar to galaxies at very high redshifts ($z > 7$) , and LAEs are also the likely progenitors of present-day Milky Way-like galaxies. Here we present results from the HETDEX pilot survey, which discovered ~100 LAEs with a single integral field spectrograph mounted on the McDonald Observatory 2.7m telescope. We have detected rest-frame optical emission lines from five of these galaxies with the single-slit NIR spectrograph NIRSPEC on the Keck II 10m telescope. From the ratio of the upper limit on the (undetected) [NII] flux to the observed Halpha line strength, all five LAEs appear to have low metallicities (< 50% solar). The brightest LAE in our sample lies significantly below the mass-metallicity relation for continuum-selected galaxies at the same redshift. The remaining LAEs may also lie below this relation, however their fainter Halpha fluxes result in higher limits on the [NII]/Halpha flux ratio. Thus deeper integrations, requiring multi-object spectrographs (MOS) to be feasible, are necessary. The field-of-view of the next generation of MOS NIR spectrographs will be able to simultaneously observe > 10 HETDEX LAEs to a much deeper depth, providing a significant boost in our ability to probe the chemical enrichment of this enigmatic galaxy population.

424.17 – **HETDEX: Synergy with HyperSuprime Camera**

Jenny E. Greene[1], K. Gebhardt[2], E. Komatsu[2], HETDEX collaboration

[1]Princeton University, [2]UT Austin.

9:00 AM - 2:00 PM

The upcoming HyperSuprime Cam (HSC) survey will be highly complementary to HETDEX. As one example, continuum measurements from HSC will allow efficient selection of Ly alpha emitters, while redshifts from HETDEX will improve the photometric redshift calibrations for HSC. We discuss further scientific overlap of these two large surveys.

424.18 – **VIRUS Parallel Observations with The Hobby-Eberly Telescope**

Stephen C. Odewahn[1], N. Drory[2], K. Gebhardt[3], R. de Jong[4], C. Allende Prieto[5], M. Shetrone[3], S. Tuttle[3], HETDEX Collaboration

[1]Hobby-Eberly Telescope, [2]Instituto de Astronomia, UNMA, Mexico, [3]Univ. of Texas, [4]AIP, Germany, [5]Instituto de Astrofisica de Canarias, Spain.

9:00 AM - 2:00 PM

The VIRUS spectrograph will be installed on the upgraded Hobby-Eberly Telescope (HET) in the Spring of 2012. This instrument will feature an array of integral field units and will be used primarily to conduct a survey for the HET Dark Energy Experiment (HETDEX). The VIRUS instrument will be configured to allow parallel observations during the times when the High-, Medium- and Low-Resolution Spectrographs are operating as the primary instruments on HET. This parallel mode of observing will be enabled long after HETDEX is completed and VIRUS becomes a service instrument on HET. In an effort to explore various scientific uses for such parallel data, we have taken the record of all HET observations for the years 2003 through 2009 and estimated the sky coverage that VIRUS parallel data would have provided. We have used the IFU footprint of VIRUS as it is currently configured, and all observations with the HET spectrographs that meet criteria such as length of exposure time, sky brightness, galactic latitude; and positionally cross-matched these data with various catalogs, such as USNOB2.0, to assess the number of stars and galaxies that would have been detected in a VIRUS parallel program. We review these results here and present plans for software tools that will allow HET users to plan parallel programs.

424.19 – **HETDEX: Developing the HET's Second Generation Low Resolution Spectrograph for Probing Lyman-alpha Emitting Galaxies**

Taylor S. Chonis[1], G. J. Hill[2], H. Lee[2], S. E. Tuttle[2], B. L. Vattiat[2], K. Gebhardt[1], S. L. Finkelstein[1], J. J. Adams[3], HETDEX Collaboration

[1]University of Texas at Austin, [2]McDonald Observatory, [3]Carnegie Observatories.

9:00 AM - 2:00 PM

HETDEX will map the power spectrum of 0.8 million blindly discovered Lyman-alpha Emitting Galaxies (LAE) using a revolutionary new array of massively replicated fiber-fed spectrographs dubbed the Visible Integral-Field Replicable Unit Spectrograph (VIRUS). In the era of the Hobby-Eberly Telescope wide-field upgrade and VIRUS, the current Low Resolution Spectrograph (LRS) must be replaced with a fiber instrument. We discuss the development of the second generation LRS (LRS2), which is a multi-channel instrument based on the VIRUS design. In its current design phase, it is fed by a 287 fiber microlens coupled integral field unit that covers 7" x 12" with 0.62" resolution. The instrument covers 3720 Å to 4700 Å at $R \approx 1900$ and 4600 Å to 7000 Å at $R \approx 1200$. With the purpose of making the instrument ideal for follow-up observations of LAE in the HETDEX survey, we discuss the science drivers for selecting the instrument's spectral resolution. We test the utility of the instrument and pilot a future study with LRS2 by presenting $R \approx 2000$ spectra taken with the VIRUS prototype spectrograph (VIRUS-P) in a high-resolution mode at the McDonald Observatory Harlan J. Smith 2.7 m telescope. These LAE were originally discovered in the

HETDEX Pilot Survey and their Lyman-alpha line profiles are constrained by near-infrared observations of rest-frame optical emission lines that set the systemic redshift of the galaxies. We discuss the velocity offsets of the Lyman-alpha line from the systemic line center and compare the line profiles to theoretical predictions and to similar observations for Lyman-break galaxies. Our observations provide an example of how LRS2 can be used to probe Lyman-alpha emission in $2 < z < 3$ star forming galaxies.

424.20 – **HETDEX: VIRUS Spectrographs Assembly and Alignment**

Travis Prochaska[1], J. L. Marshall[1], D. L. DePoy[1], E. Boster[1], W. Meador[1], R. Allen[1], G. J. Hill[2], HETDEX Collaboration

[1]*Texas A&M University,* [2]*University of Texas--Austin.*

9:00 AM - 2:00 PM

We describe the assembly and optical alignment process used to construct the Visual Integral-Field Replicable Unit Spectrograph (VIRUS) instrument. VIRUS is a set of 150+ optical spectrographs designed to support observations for the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX). To meet the accuracy, interchangeability, time and cost constraints, a production line will be set up to construct and test modular subassemblies in parallel. To facilitate the VIRUS production, fixtures and adjustment mechanisms have been designed to aid in assembly and alignment. This poster describes the details and operations of the camera mirror, collimator mirror and grating adjustment mechanisms, as well as the fold flat mirror alignment fixture.

424.21 – **HETDEX: Optical Alignment Of The Virus Spectrographs**

Emily Martin[1], J. Marshall[1], J. Rheault[1], D. DePoy[1], T. Prochaska[1], R. Allen[1], G. Hill[2], HETDEX Collaboration

[1]*Texas A&M University,* [2]*University of Texas.*

9:00 AM - 2:00 PM

We present an optical alignment procedure for the Visible Integral-Field Replicable Unit Spectrograph (VIRUS) collimator. Texas A&M is helping to build the VIRUS spectrographs, designed in collaboration with The University of Texas at Austin. The Hobby Eberly Telescope Dark Energy Experiment (HETDEX) will use as many as 192 units of this instrument to search for answers regarding Dark Energy. Texas A&M is currently assembling the collimators for VIRUS and designing alignment fixtures to aid in the assembly. We used ZEMAX models of VIRUS optics made by UT engineers to analyze various alignment methods we have considered. Our current plan uses two steps to properly align the collimator within the tolerance of 0.1-degrees. This will permit interchangeability among the various VIRUS parts.

424.22 – **Hetdex: Virus Instrument**

Hanshin Lee[1], G. J. Hill[1], D. L. DePoy[2], S. Tuttle[1], J. L. Marshall[2], B. L. Vattiat[1], T. Prochaska[2], T. S. Chonis[3], R. Allen[2], HETDEX Collaboration

[1]*McDonald Observatory, UT Austin,* [2]*Department of Physics and Astronomy, Texas A&M University,* [3]*Department of Astronomy, UT Austin.*

9:00 AM - 2:00 PM

The Visible Integral-field-unit Replicable Unit Spectrograph (VIRUS) instrument is made up of 150+ individually compact and identical spectrographs, each fed by a fiber integral-field unit. The instrument provides integral field spectroscopy at wavelengths between 350nm and 550nm of over 33,600 spatial elements per observation, each 1.8 sq. arcsec on the sky, at R ~ 700. The instrument will be fed by a new wide-field corrector (WFC) of the Hobby-Eberly Telescope (HET) with increased science field of view as large as 22arcmin diameter and telescope aperture of 10m. This will enable the HETDEX, a large area blind survey of Lyman-alpha emitting galaxies at redshift $z < 3.5$. The status of VIRUS instrument construction is summarized.

424.23 – **HETDEX: Diffuse Lyman-Alpha Emission**

Sarah E. Tuttle[1], S. Finkelstein[1], K. Gebhardt[1], HETDEX Collaboration

[1]*University of Texas at Austin.*

9:00 AM - 2:00 PM

The intermediate redshift universe probed by HETDEX, $1.8 < z < 3.0$, holds a great deal of information about star formation and the evolution of galaxies. Although simulations reveal a regime active with gas accretion and feeding of galaxies via filaments, observational evidence for this accretion from the Intergalactic Medium (IGM) at any redshift has been very limited. Here we use data from VIRUS-P across several well-characterized fields to put limits on diffuse emission of Lyman-Alpha at the outskirts of galaxies. This work is done in preparation for a similar program with the full HETDEX sample of Lyman-Alpha Emitters (LAEs).

424.24 – **HETDEX: Public Data Products**

Mark E. Cornell[1], J. M. Snigula[2], N. Drory[3], M. Fabricius[2], M. Landriau[2], G. J. Hill[1], K. Gebhardt[4], HETDEX Collaboration

[1]*McDonald Observatory,* [2]*MPE, Germany,* [3]*Instituto de Astronomia, UNAM, Mexico,* [4]*University of Texas.*

9:00 AM - 2:00 PM

The Hobby-Eberly Telescope Dark Energy Experiment (HETDEX) is a blind spectroscopic survey to map the evolution of dark energy using Lyman-alpha emitting galaxies as tracers. The survey instrument, VIRUS, consists of 75 IFUs distributed across the 22-arcmin field of the upgraded 9.2-m HET. Each 50x50 sq. arcsec IFU is made up of 448 1.5-arcsec fibers, and feeds a pair of spectrographs with a fixed bandpass of 350-550 nm and resolving power R~700. Each exposure gathers 33,600 spectra. Three dithers fill the area of an IFU. Observing 20 minutes per field, we reach a line flux limit of 3.5e-17 ergs-sec-1-cm-2 and mAB~22. The baseline survey will deliver spectra of 0.8M LAEs in a 9 cubic Gpc volume with $1.9 < z < 3.5$, and 1M [OII] emitters with $z < 0.48$. In addition, the survey will cover 0.4M other galaxies, 0.25M stars, 2000 galaxy clusters, 7000 QSOs with $z < 3.5$, and 20,000 NVSS radio sources. The main survey area of 42x7 sq. deg. is centered at 13hr, +53deg. Within that 300 sq. deg. region we cover 1/4.5 with fibers; thus 60 sq. deg. of sky have spectra. Initial observations will be conducted from Spring 2013 through Spring 2015. Survey extensions are planned, including an equatorial field centered on 1.5hr, 0deg, covering 28x8 sq. deg. We expect a Year 1 data release 14 months after completion of the first year of observations, a Years 1-3 data release in Spring 2016, and then a full data release including any extensions. Each data release will consist of all flux-calibrated spectra, their absolute positions on the sky to 1 arcsec, and a timestamp.

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425 – The Wide-field Infrared Survey Explorer (WISE): Science Frontiers and Final Data Release

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

425.01 – **Calculating the Yarkovsky Effect for Main-Belt Asteroids using the Rotating, Cratered Thermophysical Asteroid Model**

Drummond Fielding[1], E. L. Wright[2]

[1]*JHU Department of Physics & Astronomy,* [2]*UCLA Dept. of Physics & Astronomy.*

9:00 AM - 2:00 PM

The thermal inertia of a rotating asteroid causes its infrared radiation to reach a maximum on the “afternoon” side, and thus an imbalance in emission of thermal photons. This excess creates a net momentum transfer, imparting a force on the asteroid known as the Yarkovsky effect. This paper presents a method for calculating the Yarkovsky effect using the Rotating, Cratered Thermophysical Asteroid Model (RCTAM) to generate infrared fluxes and effective temperatures across the asteroid’s surface. The RCTAM constrains diameter, north-pole orientation, and dimensionless thermal inertia parameter - these determine the Yarkovsky force’s magnitude and direction. Net change in angular momentum per orbit is established using the best-fit set of parameters to calculate the torque from the Yarkovsky effect at 12 points along the asteroid’s orbit. The Yarkovsky effect is believed to cause the gradual injection of main-belt asteroids into orbital resonances with Jupiter and Mars. The method detailed in this paper enables calculation of the timescale necessary to move an asteroid into these resonances.

This project was supported by grant NSF-PHY 0850501 from the National Science Foundation as part of the University of California Los Angeles’s Physics and Astronomy Research Experience for Undergraduates.

425.02 – **A Newly-Discovered Yellow (D') Symbiotic System**

Bruce McCollum[1], C. Tsai[1], T. Jarrett[1], D. Stern[2], M. Skrutskie[3], R. Griffith[2], D. L. Padgett[1], D. I. Hoffman[1], S. A. Stanford[4], P. R. Eisenhardt[2], E. L. Wright[5]

[1]*IPAC/Caltech,* [2]*JPL,* [3]*Univ. of Virginia,* [4]*U.C. Davis,* [5]*UCLA.*

9:00 AM - 2:00 PM

We have discovered an unresolved object which appeared as an outlier in a WISE survey of luminous infrared galaxy candidates, whose optical+IR SED cannot be matched well by model SEDs of galaxies or AGNs. The 2MASS IR colors of this object are not consistent with those of MS stars, Be stars, CV stars, or PNe, but fall in a region populated by dusty symbiotic stars, and at the edge of the T Tauri star region, in 2MASS color-color plots. It is not located in any known star-forming region, nor have any YSO candidates been identified nearby. Also, its r-i color is not consistent with PNe, Be stars or CV stars, but falls within the region populated by symbiotic stars. We obtained follow-up near-IR photometry which shows variability over time scales of weeks. We also obtained follow-up optical spectra in the range of ~3200A to 9500A using the Keck telescope. The optical spectrum shows emission features characteristic of symbiotic stars. Interestingly, its complex spectrum includes a CH absorption feature which is not found in the most common type of evolved companion in a symbiotic system, i.e. M type stars, but is a characteristic of early G stars. We conclude that this system is a new member of the rare category of symbiotic called yellow or D' symbiotics. Only seven of the ~200 known symbiotics are of this type.

425.03 – **WISE Flux Variables**

Douglas I. Hoffman[1], R. Cutri[1], F. Masci[1], J. Fowler[1], T. Jarrett[1], K. Marsh[1]

[1]*IPAC / Caltech.*

9:00 AM - 2:00 PM

The Wide-field Infrared Survey Explorer (WISE) mapped the entire sky in four bands centered at wavelengths of 3.4, 4.6, 12, and 22 microns. The number of exposures for each point on the sky increases with ecliptic latitude, and ranges from ~12 on the ecliptic to over 1000 at the ecliptic poles. The observing cadence is suited for studying flux variables with periods between ~2 hours to ~2 days near the ecliptic, with the maximum period increasing up to several weeks near the ecliptic poles. We present the method used to identify several types of variables in the WISE Preliminary and Final Source Databases, and the mid-IR light curves of many periodic and non-periodic variable sources. Many of these objects are new, and include RR Lyr, Algol, W UMa, Cepheid, and YSO -type variables, as well as several blazar candidates.

425.04 – **WISE Observations Of Young Stellar Objects In The L1509 Dark Cloud**

Wilson M. Liu[1], D. L. Padgett[2], S. Terebey[3], J. R. Angione[4]

[1]*IPAC/Caltech,* [2]*NASA Goddard,* [3]*California State University- Los Angeles,* [4]*JPL.*

9:00 AM - 2:00 PM

The Wide-Field Infrared Survey Explorer (WISE) has uncovered a striking cluster of young stellar objects (YSOs) associated with the L1509 dark cloud in Auriga. This group of YSOs is coincident with a dark filamentary structure in the cloud. The WISE observations, at 3.4, 4.6, 12, and 22 microns, show a number of objects with colors consistent with YSOs, and their spectral energy distributions indicate the presence of circumstellar emission around numerous sources. We have also obtained J, H, and K-band spectroscopy in order to constrain the spectral type and accretion activity for a number of sources. We present results for individual objects as well as aggregate characteristics for the cluster.

425.05 – **New Young Star Candidates in the Taurus-Auriga Region as Selected from WISE**

Luisa M. Rebull[1], X. Koenig[2], D. Padgett[3], S. Terebey[4], P. McGehee[5], L. Hillenbrand[1], G. Knapp[6], D. Leisawitz[2], W. Liu[5], A. Noriega-Crespo[1], M. Ressler[7], K. Stapelfeldt[8], S. Fajardo-Acosta[5], A. Mainzer[7]

[1]*Caltech,* [2]*GSFC,* [3]*Caltech (currently GSFC),* [4]*Cal State LA,* [5]*IPAC/Caltech,* [6]*Princeton,* [7]*JPL,* [8]*JPL (Currently GSFC).*

9:00 AM - 2:00 PM

The Taurus Molecular Cloud subtends a large solid angle on the sky, in excess of 250 square degrees. The search for legitimate Taurus members to date has been limited by sky coverage as well as the challenge of distinguishing members from field interlopers. The Wide-field Infrared Survey Explorer (WISE) has recently observed the entire sky, and we take advantage of the opportunity to search for young stellar object (YSO) candidate Taurus members from a ~260 square degree region designed to encompass previously-identified Taurus members. We use near- and mid-infrared colors to select objects with apparent infrared excesses and incorporate other catalogs of ancillary data to present: a list of rediscovered Taurus YSOs with infrared excesses (taken to be due to circumstellar disks), a list of rejected YSO candidates (largely galaxies), and a list of 94 surviving candidate new YSO-like Taurus members. There is likely to be contamination lingering in this candidate list, and follow-up spectra are warranted.

425.06 – **Wise Selection of Obscured and Unobscured AGN**

Roberto Assef[1], D. K. Stern[1]

[1]*Jet Propulsion Laboratory.*

9:00 AM - 2:00 PM

WISE is a uniquely efficient tool for finding active galactic nuclei (AGNs), identifying luminous AGN essential independent of the obscuration of the active nucleus. We discuss the WISE selection of AGN using SED modeling techniques, using the vast amount of multi-wavelength photometric and spectroscopic observations in the 10 deg2 NOAO Deep, Wide-Field Survey Bootes field (also known as the Spitzer Deep, Wide-Field Survey and XBootes) and the COSMOS field. We discuss the biases and contamination of the mid-IR color AGN selection, and the physical properties of objects found by WISE.

425.07 – **The 3.4 μm Galaxy Luminosity Function Measured Using WISE**

Sean E. Lake[1], E. L. Wright[1], S. Petty[1], R. J. Assef[2], S. A. Stanford[3], D. K. Stern[2]

[1]*UCLA,* [2]*JPL CalTech,* [3]*UC Davis.*

9:00 AM - 2:00 PM

We present the 3.4 μm field galaxy luminosity function as measured by *WISE* back to redshift z=0.7. Our primary source of redshifts is an optical spectroscopic survey of W1 selected objects that yielded 219 redshifts for sources with 3.4 μm flux >= 80 μJy. We show both Schecter function fits to the luminosity function and non-parametric V/Vmax based estimates. Lastly, we utilize several large public redshift databases to perform parallel luminosity function measurements that we compare and then merge after removing the biases relative to a 3.4 μm selected survey.

425.08 – **The Infrared Properties of Sources in the H-ATLAS and WISE Surveys**

Nicholas A. Bond[1], D. Benford[1], J. P. Gardner[1]

[1]*NASA/Goddard.*

9:00 AM - 2:00 PM

We describe the infrared properties of sources detected over ~36 square degrees of sky in the GAMA 15-hr equatorial field, using data from both the Herschel Astrophysical Terahertz Large-Area Survey (H-ATLAS) and Wide-field Infrared Survey (WISE). With point-source depths of 34 and 0.06 mJy at 250 micron and 3.4 micron, respectively, we are able to identify 50.4% of the H-ATLAS sources in the WISE survey, two-thirds of which have measured spectroscopic or optical/near-IR photometric redshifts of $z>1.5$ based on their small 3.4-250 micron flux ratios, large AGN fraction (~25%), and small 250-350 micron flux ratios. If these sources have a median redshift of z~2, a comparison to spectral templates of dust-obscured galaxies suggests that these galaxies are forming stars at a rate that would double their mass every half billion years. Finally, for sources with spectroscopic redshifts at $z<0.4$, we find a linear correlation between the infrared luminosity at 3.4 micron and that at 250 micron, with +- 50% scatter over two orders of magnitude in luminosity, ~10^9 - 10^{11} solar luminosities.

425.09 – **Improving the Precision of Stellar Astrometry of IRAC Channel 1 Observations**

Kenneth J. Mighell[1]

[1]*National Optical Astronomy Observatory.*

9:00 AM - 2:00 PM

The measured distance between two stars on a single Spitzer Space Telescope Infrared Array Camera (IRAC) Channel 1 (Ch1) BCD image can be systematically off by as much as one-fifth of a pixel which is 0.24 arcsec on the sky -- if standard intensity-weighted mean centroids are calculated (Mighell, Glaccum, & Hoffman 2008). The square centroid error distribution is well modeled by using a Point Spread Function (PSF) described by a diffraction-limited Airy pattern at 3.6 microns with a 60 percent circular central obscuration. This simple model describes (1) the separability of the centroid errors in the X and Y direction, (2) the size (amplitude) of the maximum centroid errors in X and Y, and (3) the shape (nearly sinusoidal) and (almost) the phase of the separable centroid errors as a function of X and Y pixel phase. The primary physical cause of the square centroid error distribution is that the space-based nearly-diffraction-limited PSF of the IRAC Ch1 PSF was strongly undersampled at the focal plane of the IRAC Ch1 camera by its detector array. This work has been supported by a grant from the National Aeronautics and Space Administration (NASA), NNX10AD45G, which was awarded by the Astrophysics Data Analysis Program (ADAP) of NASA's Science Mission Directorate.

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426 – Intergalactic Medium, QSO Absorption Line Systems

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

426.01 – **He Ii Lyβ Gunn-peterson Absorption: New Hst Observations, And Theoretical Expectations**

David Syphers[1], S. F. Anderson[2], W. Zheng[3], B. Smith[4], M. Pieri[5]

[1]*University of Colorado,* [2]*University of Washington,* [3]*Johns Hopkins University,* [4]*Michigan State University,* [5]*University of Portsmouth, United Kingdom.*

9:00 AM - 2:00 PM

Observations of He II Lyα Gunn-Peterson troughs have proved to be a valuable probe of the epoch of helium reionization at z ~ 3. Since this optical depth can become unmeasurably large even for modest He II fractions, various alternate techniques have been proposed to push to higher redshift, and among the more promising is looking at higher order Lyman-series troughs. We here report four new observations of the He II Lyβ trough, including new data on the only sightline with a prior Lyβ observation. However, the effective optical depth ratio $\tau_{eff,\beta}/\tau_{eff,\alpha}$ is not simply predicted by $f_\beta\lambda_\beta/f_\alpha\lambda_\alpha = 0.16$, and we analyze cosmological simulations to find that the correct ratio for helium at z ~ 3 is 0.35. In one case we infer $\tau_{eff,\alpha} > 8.8$, strong evidence that helium was not fully reionized at z = 3.2-3.5, in agreement with previous measurements suggesting a later completion of reionization.

Support for HST Programs number 12178 and 12249 was provided by NASA through grants from the Space Telescope Science Institute.

426.02 – **Detection of a Milky Way Analog in a z ~ Quasar 2175 Å Dust**

Absorber System

Michael Steinke[1], J. Ge[1], A. Murrah[1], E. Grafer[1], H. Zhou[2]

[1]University of Florida, [2]University of Science and Technology of China, China.
9:00 AM - 2:00 PM

We present in this paper an analysis of the spectrum of a quasar 2175 Å dust absorber in the SDSS DR7 data. The spectrum shows clear detection of molecular hydrogen absorption bands in the near UV wavelengths and neutral carbon absorption lines in the optical wavelengths. The measured equivalent widths of CI λ 1656 and 1560 Å lines and the v = 0-0, 1-0, 2-0, and 3-0 Lyman bands of molecular hydrogen are among the strongest ones in high redshift quasar absorbers ever detected. The [Zn II] and [Cr II] measurements indicate that this system is a metal rich system and a heavily dust depleted system, consistent with the strong 2175 Å dust extinction bump detected in this system. All of the measurements indicate that this may be a Milky Way analog in the early universe.

426.03 – **Thermal And Dynamical Properties Of C IV Absorbers (1.5 < z < 3.5)**

Drake Ranquist[1], T. Kim[2]

[1]Brigham Young University, [2]University of Wisconsin--Madison.
9:00 AM - 2:00 PM

The majority of baryonic matter at high redshifts is located within the intergalactic medium (IGM). In particular, the circum-galactic material (CGM) surrounding galaxy-forming regions plays a vital role in the formation and evolution of galaxies due to feedback between the infalling IGM and the outflows from star formation. Using 17 QSO spectra taken with the Ultraviolet and Visible Echelle Spectrograph (UVES) at the European Southern Observatory (ESO), we determined thermal and non-thermal motions of CIV absorbers at $1.5 < z < 3.5$. We selected a sample of HI and CIV systems that exhibited the same profiles (the systems are cospatial). These absorption lines were then fit with Voigt profiles to derive the line width (the b parameter which constrains the gas kinetic temperature) and the column densities. Of 42 selected HI-CIV pairs with HI column densities between 10^{12} and $10^{15.5}$ cm^{-2}, the mean temperature is 28800 K and the mean velocity from non-thermal motion is 6.34 km/s. The non-thermal energy density is only about 10% of the thermal-energy density, which implies that the CIV absorbers in our sample are dominated by thermal energy. While the local interstellar medium shows a correlation between the cloud size and the turbulent motion, the CGM does not show any correlations between derived physical parameters.

This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

426.04 – **Lyman-alpha Luminosity Function near the Epoch of Reionization**

Vithal Tilvi[1], S. Malhotra[2], J. E. Rhoads[2], H. Krug[3], S. Veilleux[3], P. Hibon[4], S. Finkelstein[5], J. Wang[6], R. Swaters[3], R. Probst[7], C. Papovich[1], M. Dickinson[7]

[1]Texas A&M, [2]Arizona State University, [3]University of Maryland, [4]Gemini, Chile, [5]U T Austin, [6]CSTC, China, [7]NOAO.
9:00 AM - 2:00 PM

Lyman-alpha (Lya) emitting galaxies at high-redshifts provide an unique probe of cosmological reionization since the observed number density of Lya galaxies depends on the degree of ionization of the intergalactic medium (IGM). In addition, they are also a good tool to study the low-mass galaxy formation at high-redshifts.

We have performed two deep near-infrared narrowband (NB) imaging surveys in the EGS field using two custom-designed narrowband filters on the NEWFIRM imager, to search for candidate Lya galaxies at z~8. In a total survey volume of ~2.8×10^4 Mpc^3, with survey sensitivity >8×10^{-18} $erg/s/cm^2$, we have found one candidate Lya galaxy at z=7.7. While spectroscopic confirmations are necessary, combining these observations with a previous NB survey, we find that the Lya luminosity function (LF) at z=7.7 is consistent with the LF at z=6.6 suggesting that the IGM is still relatively ionized even at z=7.7. Using the spectroscopic followup of four candidate Lya galaxies from our previous NB imaging survey, we disfavor only the brightest candidate as a real galaxy at z=7.7. Future, more sensitive spectroscopic observations are needed for robust conclusions about the remaining candidates.

426.05 – **Spectral Response of the OII Spatial Heterodyne Spectrometer**

Roberto Rodriguez[1], E. J. Mierkiewicz[2]

[1]University of Puerto Rico at Humacao, [2]University of Wisconsin-Madison.
9:00 AM - 2:00 PM

This paper describes spectral and intensity calibration of a Spatial Heterodyne Spectrometer (SHS) designed to observe radial velocity resolved profiles of diffuse [OII] 3726 Å and 3729 Å emission lines from the warm (10^4 K), low-density (10^{-1} cm^{-3}), ionized component of our Galaxy's interstellar medium. Measurements were carried out using calibration lamp and sky data in order to assess the [OII] SHS's sensitivity as a function of input aperture, a necessary step in the analysis of planetary nebula (PNe) datasets to be used in the instrument's final intensity calibration. Fully calibrated [OII] line intensities will help quantify variations in temperature and in ionization state within the WIM. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

426.06 – **Orbiting Cool Halo Gas: Observing the End of Cold Mode Gas Accretion onto Galaxies**

Kyle Stewart[1], T. Kaufmann[2], J. Bullock[3], E. Barton[3], A. Maller[4], J. Diemand[5], J. Wadsley[6], L. Moustakas[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [2]Institute for Astronomy, ETH Zurich, CH-8093 Zurich, Switzerland, [3]Center for Cosmology, Department of Physics and Astron- omy, The University of California at Irvine, Irvine, CA, 92697, [4]Department of Physics, New York City College of Technol- ogy, 300 Jay St., Brooklyn, NY 11201, [5]Institute for Theoretical Physics, University of Zurich, 8057, Zurich, Switzerland, [6]Department of Physics and Astronomy, McMaster Univer- sity, Main Street West, Hamilton L85 4M1, Canada.
9:00 AM - 2:00 PM

We use cosmological hydrodynamic simulations to study the kinematic signatures of gas accretion onto a pair of well-resolved galaxy halos. We find that cold-flow streams and gas-rich mergers produce a circum-galactic component of cool gas that generally rotates about the galaxy halo before eventually falling in to build the disk. This signature of cosmological accretion should be observable in absorption line studies as gas absorption features that are offset from the galaxy's systemic velocity and that typically co-rotate with the central disk, and has already been seen in studies of intermediate redshift galaxy-absorber pairs. The cool circum-galactic component drops precipitously once the galaxies cross the critical mass to form stable shocks, Mvir = Mshock ~ 10^{12} Msun. Before reaching Mshock, the galaxies experience cold mode accretion (T < 10^5 K) and show moderately high covering fractions in this co-rotating, accreted gas: ~ 30-50% for R<50 co-moving kpc and $N_{HI} > 10^{16}$ cm^{-2}. Within ~500 Myr of crossing the Mshock threshold, each galaxy transitions to hot mode gas accretion, and the covering fraction drops to ~5%. This sharp transition is primarily a function of halo mass, not redshift. As a result, the fraction of rotating absorption-lines should decrease around bright galaxies at low redshift as cold mode accretion dies out, a trend that should be detectable in absorption system studies that target galaxies of varying host mass. This signature provides a direct observational tracer of the transition from cold flow accretion to hot mode accretion in galaxies.

426.07 – **A Standardized Catalog of 242 MgII Absorption-Selected Galaxies: Correlations, Covering Fractions, and Cantankerous Outliers**

Nikole M. Nielsen[1], C. W. Churchill[1]

[1]New Mexico State University.
9:00 AM - 2:00 PM

We conducted an extensive literature search for z<1 spectroscopically confirmed MgII absorption-selected galaxies. We standardized the galaxy impact parameters, k-corrections, absolute AB magnitudes, and rest-frame colors to Ω_m=0.3, Ω_k=0.0, Ω_Λ=0.7 cosmology. The full sample comprises 242 galaxies, where 44 are ambiguous identifications or group galaxies. Selected results based on the remaining 198 galaxies include: (1) an 8.6 σ anti-correlation between W(2796) and impact parameter, and (2) a confirmation of the gas halo size-luminosity scaling with R*=106 kpc and β=0.35 for W(2796)>0.1 Ǻ. Within the gas halo the fraction of absorbers increases as the EW threshold is decreased such that 27% have EW>1.0 Å, 47% for EW>0.6 Å, 72% for EW>0.3 Å, and 85% for EW>0.1 Å. The full sample and further analysis are presented.

426.08 – **Large-scale Spatial Fluctuations in Metal Enrichment during Reionization**

Mia S. Bovill[1], P. R. Shapiro[1], I. T. Iliev[2], G. Mellema[3], Y. Mao[1], K. Ahn[4]

[1]University of Texas at Austin, [2]University of Sussex, United Kingdom, [3]Stockhom University, Sweden, [4]Chosun University, Korea, Republic of.
9:00 AM - 2:00 PM

The massive stars believed responsible for cosmic reionization also formed the first metals, subsequently enriching their host galaxies and the intergalactic medium (IGM). We use the results of large-scale N-body + Radiative Transfer simulations to map the evolving, inhomogeneous distribution of metals in galactic halos and the IGM during the epoch of reionization (EoR). The amount of metals injected into the IGM is determined by the number of ionizing photons required to ionize that region, the metallicity yield per ionizing photon for our assumed stellar populations, the escape fraction of ionization photons, f_esc,gamma, and of metals, f_esc,Z, from the halos. We present three-dimensional maps of the IGM metallicity at redshifts from the beginning of the EoR to its end at z > 6. Our metallicity maps will be compared to observations of the C IV abundance from quasar absorption lines at z~6. This will test our reionization model,

determine the dependence of the predicted IGM metallicity on environment and identify the local overdensities at which we can reproduce the observed abundances.

426.09 – **Probing Galaxies Through Quasar Absorption Lines with HST/COS**

Brian A. Keeney[1], J. T. Stocke[1], C. W. Danforth[1], S. V. Penton[1]

[1]*Univ. of Colorado.*

9:00 AM - 2:00 PM

With 20-30 times the throughput of the *Hubble Space Telescope*'s previous far-UV spectrographs at comparable resolution, the Cosmic Origins Spectrograph (COS) is revolutionizing studies of the low-redshift intergalactic medium (IGM). This new wealth of low-redshift IGM absorbers is important because only at the lowest redshifts can we probe the faint end of the galaxy luminosity function to determine the contribution of both dwarf and luminous galaxies to IGM enrichment. We will present results from recent studies of low-redshift galaxy/absorber associations targeted with COS as well as serendipitous associations combed from the STIS archive focusing on the extent and content of a galaxy's circumgalactic medium as a function of its luminosity.

426.10 – **IGM Absorption Environments: A Galaxy Redshift Survey**

Helen Yamamoto[1], D. Syphers[1], B. Keeney[1], J. Stocke[1]

[1]*Center for Astrophysics and Space Astronomy.*

9:00 AM - 2:00 PM

Our WIYN/ HYDRA galaxy redshift survey is designed to obtain redshifts for all galaxies with a g-magnitude less than or equal to 20 located within 20' of 39 different sightlines targeted by the COS GTO team. Data was reduced in IRAF using standard routines and the dohydra task, for spectral extraction.

The redshifts were determined by IDL code developed by D. Syphers and were then inspected by eye. The program uses three methods to automatically determine the redshift: cross-correlation using template galaxies, a wavelet search for strong emission lines, and a wavelet search for Ca H&K (and other absorption lines). Inspecting these redshifts required, for each object, a verification of the cross-correlation fit and, depending on the available spectra, a determination of proper emission and absorption features.

In conducting our survey of the 3C 263 sightline, we've discovered a number of galaxies in the vicinity of our sightline, including one that happens to be located extremely close to the sightline at the same redshift as an IGM absorber seen in the QSO spectrum. This galaxy's activity may have contributed to our QSO spectrum, allowing us to determine whether or not material may have been ejected from these objects.

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427 – Starburst Galaxies

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

427.01 – **Resolving the Connection Between Dense Gas Properties and Star Formation in Maffei 2**

David S. Meier[1], J. L. Turner[2]

[1]*New Mexico Institute of Mining and Technology,* [2]*University of California, Los Angeles.*

9:00 AM - 2:00 PM

The intimate connection between dense gas and star formation makes characterizing evolving dense gas properties of great importance to understanding the evolution of starbursts. We present high spatial resolution (<100 pc) imaging of ten dense gas probes towards the nucleus of Maffei 2. These astrochemical observations are compiled from the OVRO, BIMA and CARMA millimeter interferometers. Line ratios between dense gas tracers including HCN/HCO^+, HCN/HNC and HCO^+/N_2H^+ are compared with local star formation rate, gas density and chemistry. The HCN/HCO^+ and HCO^+/N_2H^+ line ratios exhibit strong giant molecular cloud scale variation. Small scale variation in the HCN/HNC ratio is not observed. The HCN/HCO^+ line ratio poorly correlates with star formation, while elevated HCO^+/N_2H^+ ratios correlate well with photon-dominated regions (PDRs). The use of HCO^+/N_2H^+ as a PDR tracer in external galaxies is proposed and its distribution is compared with the lower density PDR tracer, C_2H, to characterize PDR physical conditions. The impact of photodissociation on the morphology of shock tracers is discussed. Conclusions from Maffei 2 are compared with IC 342 and M 82 to further investigate changes in gas chemistry with starburst phase.

This work is supported by the National Science Foundation grant AST-1009620.

427.02 – **Molecular Gas In The Cartwheel's "Over-Cooked" Ring**

James L. Higdon[1], S. J. U. Higdon[1]

[1]*Georgia Southern University.*

9:00 AM - 2:00 PM

We combine imaging and spectroscopic data from ISO and Spitzer to measure the molecular content of the Cartwheel's starburst outer ring. Attempts to determine the ring's H2 mass using rotational transitions of 12CO have been so far unsuccessful, despite the expectation of abundant molecular gas in the orbit crowded rings. We use these results to evaluate the ring's molecular fraction and the factors that influence it most. We also revisit the ring's peculiar star formation law and efficiency, and its large scale gravitational stability.

427.03 – **Probing the Mass Distribution and Stellar Populations of M82**

Johnny Greco[1], P. Martini[1], T. A. Thompson[1]

[1]*The Ohio State University.*

9:00 AM - 2:00 PM

M82 is often considered the archetypical starburst galaxy because of its spectacular starbust-driven superwind. Its close proximity of 3.6 Mpc and nearly edge-on geometry make it a unique laboratory for studying the physics of rapid star formation and violent galactic winds. In addition, there is evidence that it has been tidally-truncated by its interaction with M81 and therefore has essentially no dark matter halo. The mass distribution of this galaxy is needed to estimate the power of its superwind, as well as determine if a dark matter halo is still present. Numerous studies have used stellar and gas dynamics to estimate the mass distribution, yet the substantial dust attenuation has been a significant challenge. We have measured the stellar kinematics in the near-infrared K-band with the LUCI-1 spectrograph at the Large Binocular Telescope. We used the ^{12}CO stellar absorption bandhead at $2.29\mu m$ to measure the stellar rotation curve out to ~4kpc, and our results confirm that the dark matter halo is still present. This is in stark contrast with the nearly Keplerian gas dynamics measured with HI and CO emission from the interstellar medium. We estimate M82's dynamical mass to be $\sim 10^{10}$ $M_\odot$. We have also measured the equivalent width of the ^{12}CO bandhead to provide new constraints on the spatial extent of the red supergiant population. The variation in the CO equivalent width with radius clearly shows that supergiants dominate the light within 0.5kpc radius. The superwind is likely launched from this region, where we estimate the enclosed mass is 2×10^9 $M_\odot$.

427.04 – **UV-derived Star Formation Rates in a Survey of Nearby Starburst Dwarf Galaxies**

Noah P. Mitchell[1], K. B. W. McQuinn[2], E. D. Skillman[2]

[1]*St. Olaf College,* [2]*University of Minnesota.*

9:00 AM - 2:00 PM

We present an analysis of new and archival GALEX FUV and NUV images and archival SPITZER MIPS (24 micron, 70 micron and 160 micron) images of 19 nearby starburst dwarf galaxies from the sample studied by McQuinn et al. (2010a,b). These galaxies all have recent star formation histories derived from Hubble Space Telescope (HST) imaging of resolved stars. We perform background subtractions, cropping to fit HST fields of view, re-sampling of images for matched-resolution comparisons across wavelengths, and masking of foreground stars and background galaxies. Additionally, we have created a multi-wavelength archive providing the astronomical community with access to processed data sets. We compare the current star formation rates, derived from the UV emission and corrected for extinction using total IR flux estimates, to the average star formation rates derived from the optically resolved stellar populations for a variety of timescales. Our results show very good agreement for star formation rates averaged over the past 150 Myr. Partial support for this work was provided by a NASA ADAP grant (No. NNX10AD57G), a NASA GALEX grant (No. 00015662) and the NSF REU program (PHY-0851820) at the University of Minnesota.

427.05 – **The Bluest Quest: Searching For Young Stars In NGC6872**

Duilia F. De Mello[1], R. T. Eufrasio[1], T. Lakeman[1]

[1]*Catholic University of America.*

9:00 AM - 2:00 PM

NGC6872 is one of the largest spiral galaxies known (> 100 kpc). It belongs to the southern Pavo group and is interacting with a small lenticular galaxy, IC4970. We will present the latest results on our quest for the young stellar population of NGC6872 and how they correlate with the predictions from the N body simulations by Horellou and Koribalski (2007). We use multiwavelength data taken with GALEX (FUV and NUV), VLT (B, V, R, I) and Spitzer (IRAC) to estimate extinction, dust mass, ages, and star formation rate of the bluest regions of the spiral arms. We present the latest results investigating whether there is any connection between their properties and the prediction that the small nearby companion IC4970 on a low-inclination prograde passage might have caused the bluest features seen in the GALEX images.

427.06 – **HI Properties of the GOALS Luminous Infrared Galaxies**

Diana Windemuth[1], D. Frayer[2], R. Maddalena[2], S. Stierwalt[3]

[1]*Wesleyan University,* [2]*National Radio Astronomy Observatory,* [3]*California Institute of Technology.*
9:00 AM - 2:00 PM

The Great Observatories All-sky LIRG Survey (GOALS) sample of luminous infrared galaxies (LIRGs) represent the most luminous local systems in the local universe. LIRGs show enhanced starbursts and AGN activity, typically related to interacting galaxies and mergers events. We present 162 reduced HI profiles of local LIRGs measured with the GBT. We discuss our findings on the HI properties of local LIRGs, including our analyses on HI mass density as a function of infrared luminosity (LIR) normalized by the dynamical mass, HI linewidth and gas fraction as functions of LIR, as well as the observed correlation between normalized HI mass and LIR. This research was carried out at the National Radio Astronomy Observatory (NRAO) in Green Bank, a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

427.07 – **EVLA Radio Continuum Observations of the Nuclear Starburst in NGC 2146**

Joshua Marvil[1], F. Owen[2], J. Eilek[1]

[1]*New Mexico Tech,* [2]*National Radio Astronomy Observatory.*
9:00 AM - 2:00 PM

We present radio continuum images of the nuclear starburst region in NGC 2146, at ~25 frequencies between 1 and 50 GHz, using data acquired with the EVLA. Our spatial resolution of 1.5 arcseconds at all frequencies allows us to study variations in the radio continuum spectra, on scales of ~100 parsecs, over the entire starburst region (~3 kpc). We use several tools to analyze these resolved spectra, e.g. fitting simple, descriptive functions, and producing intensity-weighted images of the spectral index and curvature. We observe that the brightest peaks are predominantly flat-spectrum, whereas the faint emission in the periphery of the nuclear source is quite steep. The source emission is interpreted as a collection of unresolved HII regions and young supernova remnants, plus diffuse synchrotron from primary and secondary cosmic ray electrons. We also use these resolved spectra to investigate the composite nature of the spatially-integrated spectrum, which appears to be a featureless power-law over this frequency range.

427.08 – **Characterizing Radio Emission from Nearby LIRGs and ULIRGs**

Ashley Reichardt[1], A. K. Leroy[2], A. S. Evans[2], E. Momjian[2], E. Murphy[3], EVLA U/LIRG Collaboration (Ott, Armus, Condon, Haan, Mazzarella, Meier, Privon, Schinnerer, et al.)

[1]*University of Pennsylvania,* [2]*National Radio Astronomy Observatory,* [3]*Observatories of the Carnegie Institution for Science.*
9:00 AM - 2:00 PM

We have used the Expanded Very Large Array (EVLA) to image 22 nearby luminous and ultraluminous infrared galaxies (LIRGs and ULIRGs) at high angular resolution across a wide frequency range. We observed both C-band (4-8 GHz) and Ka-band (26.5-40 GHz) emission from each target in all four configurations of the EVLA (A, B, C, and D). We present the first combined wide-band, all-configuration images of these targets. The unique frequency coverage and high angular resolution of our data allow a much deeper look at the deeply embedded star formation and active galactic nuclei (AGN) activity in these most luminous galaxies in the local universe. The data yield resolved spectral index measurements, high resolution maps of star formation, and fill in previously unexplored parts of the radio spectral energy distribution for these objects.

427.09 – **Massive Star Formation in Extreme Galaxies Using Radio Recombination Lines**

Amanda A. Kepley[1], D. Balser[2], L. Chomiuk[3], W. Goss[2], K. Johnson[1], D. Meier[4], D. Pisano[5], A. Pope[6]

[1]*University of Virginia,* [2]*NRAO,* [3]*Harvard Smithsonian Center for Astrophysics,* [4]*New Mexico Tech,* [5]*West Virginia University,* [6]*University of Massachusetts--Amherst.*
9:00 AM - 2:00 PM

I will present results showing the state of the art observations of the ionized gas in young star-forming regions in galaxies with extremely high star formation rates. Measuring the density, mass, and kinematics of the ionized gas in these regions tells us about the state of the interstellar medium in young star-forming regions and about the massive stars themselves. Unfortunately, the state of the ionized gas is difficult to determine in the optical due to the high extinction from the remnants of the surrounding natal cocoon of dust and gas. The ionized gas in these obscured regions can be more accurately traced using radio recombination lines (RRLs). RRLs have been difficult to detect in galaxies other than the brightest dozen nearby starburst galaxies because of the limited sensitivity and bandwidth of the previous generation of radio telescopes. RRL observations of fainter and more distant galaxies are now possible with the recent enormous improvements in radio telescope instrumentation. Our RRL observations showcase the power of these revitalized tracers of the ionized gas in young star-forming galaxies.

427.10 – **Blue Compact Dwarf Galaxies: Characteristics and Relations to their Environment**

Meryl Sell[1]

[1]*University of Wisconsin - Madison.*
9:00 AM - 2:00 PM

A representative sample of 89 nearby (D<17.3 Mpc) blue compact dwarf galaxies (BCDGs) was selected for a study of their surrounding environments. The BCDGs were categorized into five groups based on galaxy morphology. Our study shows these BCDGs as having nearly completely random properties in terms of absolute magnitude, redshift, and surrounding environment. The only environmental correlation found was of BCDGs within the Virgo cluster as being single nucleated with a diffuse elliptical halo, characterized as morphological class nE. Given the uniformity of properties in such different circumstances, we hypothesize that a variety of physical processes may lead to the BCDG phenomenon. Obvious interactions involving dwarfs, however, are clearly a factor in a minority of BCDGs, and we therefore explore whether interactions could have a wider role than previously recognized. By comparing interacting galaxies with seemingly isolated BCDGs, we investigate the possibility that interactions with dark matter halos could be a factor in producing the more isolated and apparently non-interacting BCDGs.

427.11 – **Temperature and Heating Mechanisms in the Polar Ring Galaxy NGC660**

Brian E. Svoboda[1], J. G. Mangum[2]

[1]*Western Washington University,* [2]*National Radio Astronomy Observatory.*
9:00 AM - 2:00 PM

We present spectroscopically resolved GBT observations of the NH_3 (J,K) = (1,1),(2,1), (2,2), (3,3), (4,4), (5,5), (6,6), and (7,7) inversion transitions and the H_2CO J_K_{-1},K_{+1}= 1_{10}-1_{11} and 2_{11}-2_{12} transitions toward the starburst and polar ring galaxy NGC660. Four components were observed in the spectra. One component is placed in the ring and two in the disk by comparing the NH_3 fits with spatially resolved OH and HI absorption maps. The placement of the remaining component was indeterminate. We derive an average kinetic temperature of $T_K = 150 \pm 15$ K toward the nuclear region from LVG radiative transfer models of the NH_3 measurements and place limits on the galactic disk spatial density between $n(H_2) = 10^{5.03}$ - $10^{5.34}$ cm^{-3}.The high kinetic temperature in the polar ring and relative abundance $N(NH_3)/N(H_2CO) \approx 10^3$ - 10^4 is found to be consistent with recent models of ISM heating by photon dominated regions and mechanical heating, with a negligible contribution from cosmic ray heating.

427.12 – **Herschel-SPIRE Imaging Spectroscopy of Molecular Gas in M82**

Julia R. Kamenetzky[1], J. Glenn[1], N. Rangwala[1], P. R. Maloney[1], C. D. Wilson[2], M. Bradford[3], G. J. Bendo[4], SPIRE Local Galaxies Working Group (SAG 2): Very Nearby Galaxies Survey

[1]*University of Colorado at Boulder,* [2]*McMaster University, Canada,* [3]*California Institute of Technology,* [4]*University of Manchester, United Kingdom.*
9:00 AM - 2:00 PM

We present new Herschel-SPIRE imaging spectroscopy (194-671 micron) of the bright starburst galaxy M82. Covering the CO ladder from J=4-3 to J=13-12, these spectra were obtained at multiple positions for a fully sampled ~ 3 x 3 arcminute map, as well as a longer exposure at the central position. We use RADEX and a Bayesian Likelihood Analysis to model the temperature, density, column density, and filling factor of the molecular gas traced by the high-J CO transitions unavailable from the ground. We add further evidence to these lines tracing a much warmer component (> 500 K) than low-J lines. At this temperature, cooling is dominated by molecular hydrogen; we discuss the possible excitation processes in this warm component and compare to models of PDRs. SPIRE has been developed by a consortium of more than 18 institutes from eight countries led by Cardiff University (UK).

427.13 – **Herschel-SPIRE observations of Arp 220: An Unprecedented View of the Molecular Gas in an Extreme Star Formation Environment**

Naseem Rangwala[1], Herschel SAG-2 Team

[1]*University of Colorado, Boulder.*
9:00 AM - 2:00 PM

We present Herschel SPIRE-FTS observations of Arp 220, a nearby ULIRG. The FTS continuously covers 190 -- 670 microns, providing a good measurement of the continuum and detection of several molecular and atomic species. We detect luminous CO (J = 4-3 to 13-12) and water ladders with comparable total luminosity; very high-J HCN absorption; OH+, H2O+, and HF in absorption; and CI and NII. Modeling of the continuum yields warm dust, with T = 66 K, and an unusually large optical depth of ~5 at 100 microns. Non-LTE modeling of the CO shows two temperature components: cold molecular gas at T ~ 50 K and warm molecular gas at T ~1350 K. The mass of the warm gas is 10% of the cold gas, but dominates the luminosity of the CO ladder. The temperature of the warm gas is in excellent agreement with H2 rotational lines. At 1350 K, H2 dominates the cooling (~20 L_{sun}/M_{sun}) in the ISM compared to CO (~0.4

L_{sun}/M_{sun}). We found that only a non-ionizing source such as the mechanical energy from supernovae and stellar winds can excite the warm gas and satisfy the energy budget of ~20 L_{sun}/M_{sun}. We detect a massive molecular outflow in Arp 220 from the analysis of strong P-Cygni line profiles observed in OH+, H2O+, and H2O. The outflow has a mass > 10^7 M_{sun} and is bound to the nuclei with velocity < 250 km/s. The large column densities observed for these molecular ions strongly favor the existence of an X-ray luminous AGN (10^{44} ergs/s) in Arp 220.

427.14 – **Herschel SPIRE Legacy Survey (HSLS)**

Asantha R. Cooray[1]

[1]*UC Irvine.*

9:00 AM - 2:00 PM

A large sub-mm survey with Herschel will enable many exciting science opportunities, especially in an era of wide-field optical and radio surveys and high resolution cosmic microwave background experiments. The Herschel-SPIRE Legacy Survey (HSLS), will lead to imaging data over 2000 sq. degrees at 250, 350, and 500 micron. Major Goals of HSLS are: (a) produce a catalog of 1.5 million galaxies down to 26, 27 and 33 mJy (50% completeness; 5 sigma confusion noise) at 250, 350 and 500 micron, respectively, in the southern hemisphere and Stripe-82, areas which have extensive multi-wavelength coverage and are easily accessible from ALMA. Two thirds of the of the sources are expected to be at z > 1, one third at z > 2 and about a 1000 at z > 5. (b) Remove point source confusion in secondary anisotropy studies with Planck and ground-based CMB data. (c) Find at least 1500 strongly lensed bright sub-mm sources leading to a 2% test of general relativity. (d) Identify 200 proto-cluster regions at z of 2 and perform an unbiased study of the environmental dependence of star formation. (e) Perform an unbiased survey for star formation and dust at high Galactic latitude and make a census of debris disks and dust around AGB stars and white dwarfs.

In the unlikely event HSLS is not selected by ESA HOTAC, the poster will present recent results from the Herschel-ATLAS survey, the largest open-time key program aimed at covering 500 square degrees.

427.15 – **Herschel HerMES: Gravitationally Lensed Galaxies and Lensing Statistics at Submillimeter Wavelengths**

Julie L. Wardlow[1], A. Cooray[1], F. De Bernardis[1], HerMES Collaboration

[1]*University of California, Irvine.*

9:00 AM - 2:00 PM

Strong gravitational lensing provides a boost in the apparent flux and angular size of distant galaxies, enabling the study of high-redshift populations in unprecedented detail. Furthermore, the lensing distortion also establishes a measure of the total mass of the foreground deflector, and is therefore useful to study the distribution of dark matter in foreground structures. Using Herschel HerMES data we have compiled the largest catalog to date (~90 sources) of distant submillimeter galaxies (SMGs) that are candidates for being strongly gravitationally lensed by individual foreground galaxies. Candidate identification is straightforward due to the steep bright-end slope of the intrinsic SMG number counts -- we simply select sources that are brighter than 80mJy at 500μm and remove local (z<~0.1) spiral galaxies and radio-loud AGN. The candidate lensed galaxies have submillimeter colors that are consistent with high-redshift galaxies and that are typical of Herschel-selected sources. A simple model of the lensing rate, based on the intrinsic SMG number counts and a foreground dark matter distribution, predicts that our candidates have high fidelity, with 40--90% of them lensed by a factor of ≥2. The model also predicts that the average magnification of the lensed SMGs increases with apparent 500μm flux and is a factor of ~2--10 for the sources in our sample (S_{500}=80--200mJy). Follow-up programs to target the candidate lensed galaxies are ongoing and initial results confirm the lensing nature of several systems. The typical SMG in these systems lies at z~3 and is lensed by a galaxy at z~0.5. The observed lensing magnifications are factors of ~3--20, with the majority of observed sources magnified by factors <~10.

427.16 – **Identifying Extremely Red H-ATLAS Sources Using a Map-Based Technique**

Chris C. Frazer[1], A. Cooray[1], K. Mitchell-Wynne[1], J. L. Wardlow[1], H-ATLAS team

[1]*University of California, Irvine.*

9:00 AM - 2:00 PM

The Herschel SPIRE instrument samples flux at 250, 350 and 500 um, close to the peak emission of cold dust. Therefore, it preferentially selects active and dusty high-z sources, similar to submillimeter galaxies (the so-called "SCUBA-galaxies"). In this study, we use wide-field H-ATLAS maps to identify rare, extremely red SPIRE sources. Candidates have fluxes that increase from 250 to 350um and from 350 to 500um and are selected from a "difference map" that traces the variance between the 250um and 500um data. Blended contaminats are removed using the highest resolution 250 micron data, thus leaving a sample of rare red sources. If these extreme sources have rest-frame SEDs typical of z~2 SMGs they are expected to lie at z>~5 and represent a uniform selection of high-z dusty galaxies. For lower redshift sources to have such extreme red colors their submillimeter emission must be dominated by cold dust, and they represent a thus-far unexplored population.

427.17 – **Intensity Mapping of the [CII] Fine Structure Line during the Epoch of Reionization**

Yan Gong[1], A. Cooray[1], M. Silva[2], M. G. Santos[2], J. Bock[3], M. Bradford[3], M. Zemcov[3]

[1]*UCI,* [2]*Technical University of Lisbon, Portugal,* [3]*California Institute of Technology.*

9:00 AM - 2:00 PM

The atomic CII fine-structure line is one of the brightest lines in a typical star-forming galaxy spectrum with a luminosity ~ 0.1% to 1% of the bolometric luminosity. It is otentially a reliable tracer of the dense gas distribution at high edshifts and could provide an additional probe to the era of reionization. By taking into account of the spontaneous, stimulated and collisional emission of the CII line, we calculate the spin temperature and the mean intensity as a function of the redshift. When averaged over a cosmologically large volume, we find that the CII emission from ionized carbon in individual galaxies is larger than the signal generated by carbon in the intergalactic medium (IGM). Assuming that the CII luminosity is proportional to the carbon mass in dark matter halos, we also compute the power spectrum of the CII line intensity at various redshifts. In order to avoid the contamination from CO rotational lines at low redshift when targeting a CII survey at high redshifts, we propose the cross-correlation of CII and 21-cm line emission from high redshifts. To explore the detectability of the CII signal from reionization, we also evaluate the expected errors on the CII power spectrum and CII-21 cm cross power spectrum based on the design of the future milimeter surveys. We note that the CII-21 cm cross power spectrum contains interesting features that captures physics during reionization, including the ionized bubble sizes and the mean ionization fraction, which are challenging to measure from 21-cm data alone. We propose an instrumental concept for the reionization CII experiment targeting the frequency range of ~ 200 to 300 GHz with 1, 3 and 10 meter apertures and a bolometric spectrometer array with 64 independent spectral pixels with about 20,000 bolometers.

427.18 – **Herschel Hermes: Identifying Counterparts In CANDELS HST & SpUDS IRAC Data**

Ali Ahmad Khostovan[1], J. Wardlow[1], S. Kim[1], A. Cooray[1], HerMES Team, CANDELS Team

[1]*University of California, Irvine.*

9:00 AM - 2:00 PM

We apply a likelihood ratio (LR) test to identify Spitzer IRAC & HST counterparts to Herschel HerMES sources in the UDS field. The HerMES sources are selected from SPIRE 250, 350, & 500 micron data and are typically far-IR luminous dusty galaxies at high-z. Their extreme far-IR luminosities are driven by extreme star-formation rates, though it is unclear whether mergers play a dominant role in triggering these high-redshift starbursts. Deep, high resolution HST data are ideal for studying morphologies and merger fractions, even at high redshift. However, directly identifying SPIRE counterparts in HST data is challenging due to the large SPIRE beam and high dust extinctions in submillimeter galaxies. Here, we use Spitzer IRAC data as an intermediary between SPIRE sources and HST counterparts. To match to the IRAC data, we employ the likelihood ratio (LR) test, which determines the most likely identification for a source and the reliability that that object is the true counterpart. We apply the LR test to ~ 7000 HerMES sources in the UDS to identify their IRAC counterparts. The IRAC counterparts are then matched to HST sources, resulting in a catalog of HerMES sources with reliable identifications in CANDELS-HST data.

428 – Surveys and Large Programs

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

428.01 – **SDSS-III/APOGEE: Main Survey and Star Cluster Target Selection**

Kelly Jackson[1], G. Zasowski[2], P. M. Frinchaboy[1], J. A. Johnson[3], C. Allende Prieto[4], T. C. Beers[5], D. Bizyaev[6], J. Holtzman[7], L. Girardi[8], S. R. Majewski[9], D. Nidever[9], A. G. Perez[9], H. R. Pinto[10], R. Schiavon[11], M. Shetrone[12], M. Skrutskie[9], J. C. Wilson[9]

[1]*TCU,* [2]*U.Virginia,* [3]*OSU,* [4]*IAC, Spain,* [5]*JINA/NOAO,* [6]*APO,* [7]*NMSU,* [8]*INAF, Italy,* [9]*U. Virginia,* [10]*UFRJ, Brazil,* [11]*Gemini Observatory,* [12]*HET.*

9:00 AM - 2:00 PM

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. 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.

428.02 – **Apache Point Observatory Galactic Evolution Experiment (APOGEE) Spectrograph**

John C. Wilson[1], F. Hearty[1], M. F. Skrutskie[1], S. R. Majewski[1], R. Schiavon[2], D. Eisenstein[3], J. Gunn[4], B. Gillespie[5], D. Weinberg[6], B. Blank[7], C. Henderson[7], S. Smee[8], R. Barkhouser[8], A. Harding[8], S. Hope[8], G. Fitzgerald[9], T. Stolberg[9], J. Arns[10], M. Nelson[1], S. Brunner[1], A. Burton[1], E. Walker[1], C. Lam[1], P. Maseman[11], J. Barr[1], F. Leger[12], L. Carey[12], N. MacDonald[12], G. Ebelke[5], S. Beland[13], T. Horne[11], E. Young[14], G. Rieke[11], M. Rieke[11], T. O'Brien[6], J. Crane[15], M. Carr[4], C. Harrison[16], R. Stoll[16], M. Vernieri[16], J. Holtzman[17], D. Nidever[1], M. Shetrone[18], C. Allende-Prieto[19], J. Johnson[6], P. Frinchaboy[20], G. Zasowski[1], A. Garcia Perez[1], D. Bizyaev[5], B. Zhao[21]

[1]Univ. of Virginia, [2]Gemini Observatory, [3]Harvard University, [4]Princeton University, [5]Apache Point Observatory, [6]Ohio State University, [7]PulseRay, [8]Johns Hopkins University, [9]New England Optical Systems, [10]Kaiser Optical Systems, Inc., [11]University of Arizona, [12]University of Washington, [13]University of Colorado, [14]NASA Ames Research Center, [15]Carnegie Observatories, [16]C Technologies, [17]New Mexico State University, [18]McDonald Observatory, [19]Instituto de Astrofisica de Canarias, Spain, [20]Texas Christian University, [21]University of Florida.

9:00 AM - 2:00 PM

The Apache Point Observatory Galactic Evolution Experiment (APOGEE) will observe approximately 100,000 giant stars in the Milky Way with a dedicated fiber-fed (300 fibers from the Sloan 2.5-m telescope) near-infrared (1.5-1.7 micron) high resolution (R~22,500) spectrograph as part of the Sloan Digital Sky Survey III (SDSS-III). By observing in the near-infrared, APOGEE can uniformly sample all Milky Way stellar populations (bulge, thin/thick disks and halo) in the same survey to dramatically improve our understanding of the kinematical and chemical enrichment history of our galaxy. The instrument design includes several innovations: a novel fiber gang connector that allows simultaneous optical connection of 300 fibers from the instrument into swappable plug plate cartridges, the first deployed mosaic volume phase holographic (VPH) grating, and a very large (~0.4-m) aperture six-element refractive camera incorporating crystalline silicon elements to image 300 spectra onto three HAWAII-IIRG detectors simultaneously.

428.03 – **Stellar Cluster Abundances from APOGEE Commissioning Spectra**

Matthew D. Shetrone[1], C. Allende-Prieto[2], S. Meszaros[2], I. Ivans[3], P. Frinchaboy[4], D. Bizyaev[5], R. Schiavon[6], K. Cunha[7], V. Smith[7]

[1]Univ. of Texas, [2]Instituto de Astrofisica de Canarias, Spain, [3]Univ. of Utah, [4]Texas Christian University, [5]Apache Point Observatory, [6]Gemini Observatory, [7]NOAO.

9:00 AM - 2:00 PM

The Apache Point Observatory Galactic Evolution Experiment (APOGEE) will undertake an H-band (1.52-1.68 micron) spectroscopic survey of 1E5 red giant stars spanning the Galactic disk, bulge, and halo, with typical limiting magnitude H ~ 12.5. During the commissioning of APOGEE a number of plates containing stellar clusters were observed. Some of these star clusters are well-studied, such as M3, and others have few literatureabundance references, such as NGC 5466. We exhibit sample spectra from these clusters and give examples of the lines that can be identified at different metallicities. Metallicities and abundances are derived using a traditional equivalent width analysis with photometric stellar parameters.

428.04 – **SDSS-III/APOGEE: Star Clusters From The APOGEE "First Light" Field**

Peter M. Frinchaboy[1], C. Allende Prieto[2], T. C. Beers[3], D. Bizyaev[4], J. Holtzman[5], I. Ivans[6], K. M. Jackson[1], J. A. Johnson[7], S. R. Majewski[8], D. Nidever[8], A. Garcia Perez[8], M. Pinsonneault[7], R. Schiavon[9], M. Shetrone[10], M. Skrutskie[8], J. C. Wilson[8], G. Zasowski[8]

[1]TCU, [2]IAC, Spain, [3]JINA/NOAO, [4]APO, [5]NMSU, [6]U. Utah, [7]OSU, [8]U. Virginia, [9]Gemini Observatory, [10]HET.

9:00 AM - 2:00 PM

The Sloan Digital Sky Survey III/Apache Point Observatory Galactic Evolution Experiment (SDSS-III/APOGEE) is a large-scale spectroscopic survey of Galactic stars and star clusters. The SDSS-III/APOGEE survey is designed to produce high-S/N, R = 22,500 spectra that cover a wavelength range of 1.51 to 1.68 microns. By utilizing APOGEE's excellent kinematics (velocity errors = 0.2 km/s) and abundances (errors ~ 0.1 dex). We can study star cluster kinematics and chemical properties in detail. In this poster we present an analysis of 16 confirmed and candidate open clusters targeted in the APOGEE "first light" field, in the constellation of Cygnus. The APOGEE data are used to determine cluster membership and metallicities allowing for improved or first determinations of basic cluster parameters (age, chemistry, distance, reddening).

428.05 – **Search for CO-Emitting Galaxies in Blank Field Surveys**

Courtney D. Laughlin[1], M. Lacy[2]

[1]Virginia Polytech Institute, [2]National Radio Astronomy Observatory.

9:00 AM - 2:00 PM

Observations of molecular transitions provide insight on the study of galaxy evolution and star formation. In particular, CO is an un- ambiguous tracer of cold, dense molecular gas where stars form and proves to be an important diagnostic tool for studying early stages of galaxy formation. However, there have been very few serendipitous detections of CO emission lines, despite careful searches due to limiting detection capabilities of present telescopes. We examined nine data cubes (each with a series of frequency ranges between 30GHz and 37GHz) obtained from the Expanded Very Large Array (EVLA) in Open Shared Risk mode to search for any CO emission from field galaxies. Although the cubes that were used do not have a large enough frequency coverage to be sure of finding a real object, we were able to use data on these fields at various wavelengths to search for counterparts to candidates we did find. Once the EVLA is fully commissioned, its much wider bandwidth should make serendipitous detection of CO from field galaxies commonplace.

428.06 – **Spitzer Heritage Archive Enhanced Imaging Products**

Harry I. Teplitz[1], P. Capak[2], D. Hanish[2], T. Y. Brooke[2], J. W. Colbert[2], V. Desai[1], D. W. Hoard[2], J. Howell[1], R. Laher[2], A. Noriega-Crespo[1]

[1]Infrared Science Archive (IRSA), [2]Spitzer Science Center.

9:00 AM - 2:00 PM

The Spitzer Science Center and NASA Infrared Science Archive (IRSA) will produce and release a set of Enhanced Imaging Products from the Spitzer Heritage Archive. We anticipate a preliminary release of a subset of the data in time for the January 2012 AAS. A release of the full set of products for the Spitzer cryogenic mission will fall in mid-to-late 2012. These products will include enhanced mosaics created using data from multiple programs where appropriate and a source list (SL) of photometry for compact sources. The primary requirement on the SL is very high reliability -- with areal coverage, completeness and limiting depth being secondary considerations. The enhanced imaging products will include data from the four channels of IRAC (3-8 microns) and the 24 micron channel of MIPS. The products will be generated for Spitzer observations of about 1500 square degrees and include around 30 million sources.

428.07 – **Characterizing the Completeness of Spitzer IRAC Imaging and the GLIMPSE Point Source Catalog in High-background Regions**

Henry A. Kobulnicky[1], M. Alexander[1], B. Brian[2], M. Meade[2], B. Whitney[2], E. Churchwell[2]

[1]Univ. of Wyoming, [2]Univ. of Wisconsin.

9:00 AM - 2:00 PM

The Spitzer Space Telescope Galactic Legacy MidPlane Survey Extraordinaire (GLIMPSE) programs (GLIMPSE I, II, 3D, 360) have surveyed hundreds of square degrees of the Galactic Plane in four (two for GLIMPSE 360) mid-infrared bandpasses with the Infrared Array Camera (IRAC). The resulting GLIMPSE Point Source Catalog contains over 100 million objects and has become a widely used resource. Other large and Legacy *Spitzer* programs have used IRAC to survey additional regions totaling over 100 square degrees. The utility of the data and of the point source catalogs from ANY IRAC observations is limited, however, by the fact that the completeness of the photometric catalogs vary inversely with background surface brightness. This is especially significant in the 5.8 and 8.0 micron (IRAC1 and IRAC2) bands where diffuse interstellar PAH features are strong. In this contribution we use fake star tests to characterize the completeness and reliability of single-frame, single-band data from the commonly used short-exposure IRAC observing modes as a function of background surface brightness and stellar magnitude. We also explore empirically the completeness of the GLIMPSE Point Source Catalog as a function of background brightness and magnitude. We provide plots and analytical prescriptions to allow an end user to asses the completeness over specified magnitude and background brightness ranges.

428.08 – **SASIR: the Synoptic All-Sky Infrared Survey**

Eva Noyola[1]

[1]Instituto De Astronomia, UNAM, Mexico.

9:00 AM - 2:00 PM

We present the basic design and scientific goals of the Synoptic All-Sky Infrared Survey (SASIR). SASIR will be hosted at the Observatorio Astronómico Nacional, on the San Pedro Martir mountains in Baja California, México. In the next few years, a dedicated 6.5 meter telescope will be built to carry the project out. The camera will have a minimum field of view of 0.7 degrees across, with minimum simultaneous coverage in the J, H, and K bands. SASIR will image the entire northern sky with a general cadence of a few months, plus higher observing cadences for selected fields. The depth for the final stacked data will be a great improvement to existing all-sky infrared surveys, about 120 times deeper than 2MASS. The science areas covered by SASIR span a wide range, from the solar neighborhood to the highest redshift quasars, with particular emphasis on the transient sky, which has barely been explored in infrared wavelengths so far. The project is a joint effort between the UC system, The University of Arizona, and various Mexican institutions (led by UNAM and INAOE).

428.09 – **Analysis Of The 2mass Calibration Scan Database: Variability In The Nir From Minutes To Years**

James R. A. Davenport[1], A. C. Becker[1]

[1]*University of Washington.*
9:00 AM - 2:00 PM

The 2MASS Calibration Scan Point Source Working Database produced light curves for over 100K objects over a four year period with an average of 2000-3000 visits per field. Using this unique data source, we analyze the incidence of periodic, transient, and stochastic variations for stars and galaxies in the JHK bandpasses. Approximately 10,000 objects are matched to SDSS DR8 sources, and we describe their variability as a function of their median optical colors. These statistics will inform future time-domain studies in both the optical and NIR regime.

428.10 – **WISE View of Extragalactic Sources**

Lauren M. Anderson[1], A. R. Lewis[1], Y. AlSayyad[1], A. C. Becker[1], J. R. A. Davenport[1], N. M. Hunt-Walker[1], Z. Ivezic[1]

[1]*University of Washington.*
9:00 AM - 2:00 PM

We discuss the optical and infrared properties of galaxies and quasars selected from the Sloan Digital Sky Survey (SDSS) Data Release 8 and positionally matched to sources from the

Wide-field Infrared Survey Explorer (WISE) preliminary data release. We demonstrate that for galaxies, the

WISE [3.4]-[12] color is well correlated with the SDSS u-r color which enables better classification into the ``red sequence" or ``blue cloud" than SDSS colors alone. We also show that the WISE colors of emission-line galaxies strongly depend on their position in the Baldwin-Phillips-Terlevich (BPT) diagram and that galaxies with active galactic nuclei (AGN) have similar infrared colors as quasars. Finally, using SDSS, 2MASS and WISE bands, we construct the optical to far infrared broadband spectral energy distributions of various types of galaxies.

428.11 – **The Brightest of Reionizing Galaxies Survey: A Protocluster Candidate at redshift z~8**

Michele Trenti[1], BoRG Collective

[1]*University of Colorado.*
9:00 AM - 2:00 PM

Theoretical and numerical modeling of dark-matter halo assembly predicts that the most luminous galaxies at high redshift are surrounded by overdensities of fainter companions. We test this prediction with HST observations acquired by our Brightest of Reionizing Galaxies (BoRG) survey, finding a correlation between counts of bright and faint candidate galaxies at z~8 which is significant at >99.8% confidence. Furthermore, the best z~8 bright candidate of the survey is associated to the most significant overdensity of faint galaxies (4 additional sources within a region of diameter 70arcsec, where only 0.2 where expected), indicating that we identified a candidate protocluster at confidence >99.99%. We modeled the overdensity by means of cosmological simulations and estimate that the principal dark matter halo has mass M_h~(4-7)x10^{11}Msun (~5sigma density peak) and is surrounded by several M_h~10^{11}Msun halos which could host the fainter dropouts. In this scenario, we predict that all halos will eventually merge into a M_h>2x10^{14}Msun galaxy cluster by z=0. Follow-up observations with ground and space based telescopes are required to secure the z~8 nature of the overdensity, discover new members, and measure their precise redshift.

428.12 – **The Brightest of Reionizing Galaxies Survey: Design and Key Results**

Massimo Stiavelli[1], M. Trenti[2], BoRG Collective

[1]*STScI,* [2]*University of Colorado.*
9:00 AM - 2:00 PM

The Brightest of Reionizing Galaxies survey (BoRG) is a large Hubble Space Telescope program aimed at searching very luminous (M_AB~-21) galaxies at z~8 from wide-area, medium-deep observations in four filters (V, J, Y, H) reaching a median sensitivity of m_AB~27 at 5sigma over ~250 arcmin2. The pure-parallel nature of BoRG allows us to obtain a census of the population of rare galaxies within the epoch of reionization (700 million years after the Big Bang) without being affected by cosmic variance. The observations carried out to date led to the identification of 7 very bright candidates, two of which have been followed-up with spectroscopic observations at Keck. BoRG has been extended for the next cycle of HST observations and will cover an additional area of about 100 arcmin2 with longer exposure time, constructing a sample of observations at different depths to optimally probe the bright end of the galaxy luminosity function at z~8. In this poster we present the survey design, its key results to date and future prospects.

428.13 – **The Brightest of Reionizing Galaxies Survey: Ancillary Science at redshift z~2**

Soyoung Kim[1], M. Trenti[2], BoRG Collective

[1]*Johns Hopkins Univ.,* [2]*University of Colorado.*
9:00 AM - 2:00 PM

The BoRG survey, a large-area optical/near-IR HST program aimed at finding the most luminous z~8 galaxies, also enables the investigation of galaxy properties at z~2. Similarly to the z~8 case, the pure-parallel nature of the BoRG survey allows us to study these galaxies without being biased by cosmic variance, which affects surveys resorting to a single or a few fields. We present the typical number counts of the active and passive samples at z~2, determined using a Y-H vs. V-Y color-color selection. We discuss their clustering properties and preliminary measurements in terms of galaxy sizes and surface brightness profiles. With upcoming multi-object spectrographs such as MOSFIRE on Keck, it will be possible to derive internal kinematics and spectroscopic redshifts for a large sample of z~2 elliptical galaxies while carrying out at the same time spectroscopic confirmation of z~8 candidates.

428.14 – **Cluster Lensing And Supernova survey with Hubble (CLASH): A Magnified View of the High-Redshift Universe**

Larry D. Bradley[1], CLASH Team

[1]*Space Telescope Science Institute.*
9:00 AM - 2:00 PM

The Cluster Lensing And Supernova survey with Hubble (CLASH) is 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 goals of CLASH is the detection and characterization of z >~ 6.5 galaxies. Gravitational lensing by massive galaxy clusters can considerably amplify both the brightness and size of high-redshift sources and improves the search efficiency for relatively bright high-redshift galaxies. We will present a new sample of high-redshift galaxy candidates at z >~ 6.5 and their properties from our ongoing cluster observations.

This research is supported by NASA grant HST-GO-12065.01-A.

428.15 – **Using The Z Band For Stellar Classification: Looking Forward To Pan-starrs.**

John Vickers[1], E. Grebel[1], A. Huxor[1]

[1]*Astronomisches Rechen-Institut, Germany.*
9:00 AM - 2:00 PM

When studying blue objects (-0.3 < g-r < 0.0) in the SDSS, the u-g color has proven invaluable for the photometric splitting of white dwarfs and quasars quasars (which are quite blue), and A stars. The g-r vs u-g color space has even been shown to be quite effective at separating dwarf stars (blue stragglers, main sequence A stars) from giant (blue horizontal branch) stars since the Balmer jump at 365 nm falls into the u passband and is quite sensitive to surface gravity.

The Pan-STARRS however, lacks a u passband. New techniques must therefore be employed to separate these objects from each other. We have had success using the z filter in SDSS data as a photometric surface gravity indicator to separate high gravity main sequence A stars from low gravity blue horizontal branch stars. Quasars have also been found to separate out well with the use of the g-z color. This is fortuitous with regard to the Pan-STARRS since Pan-STARRS filter sets will roughly imitate the SDSS filter set for griz colors, so techniques developed now using SDSS data can easily be employed as soon as Pan-STARRS data becomes available.

We present the basic methodology for constructing the color cut. We show its sampling completeness using the horizontal branches of Milky Way globular clusters and its accuracy using the spectroscopic database of the Sloan Digital Sky Survey Data Release 8. Our prime result is a map of the celestial equator with many of the well known structures such as Sagittarius, Virgo, and the Hercules-Aquila cloud revealed by BHB samples.

428.16 – **The Photometric Calibration of the First Year of the Pan-STARRS 1 Survey**

Eddie Schlafly[1], D. P. Finkbeiner[1], M. Juric[1]

[1]*Harvard.*

9:00 AM - 2:00 PM

We present the photometric calibration of the Pan-STARRS 1 survey (PS1), an ongoing optical survey of the entire sky north of declination -30 in five optical bands. Following the techniques employed by Padmanabhan et al. (2007) in the Sloan Digital Sky Survey, we use repeat PS1 observations of stars to perform the relative calibration of PS1 exposures. Comparison against SDSS observations of the same stars, where available, indicates that we achieve relative accuracies of <1% in g_P1, r_P1, and i_P1, and ~1% in z_P1 and y_P1. The spatial structure of the differences with the SDSS indicates the errors come both from the SDSS and PS1 photometric calibrations, as well as from the PS1 photometry early in the survey. The results here are drawn primarily from the first year of PS1 science data, and will become more robust as the survey continues.

428.17 – **Preliminary Results of a Chandra X-ray Survey of the Norma Spiral Arm**

Francesca Fornasini[1], J. A. Tomsick[2], E. V. Gotthelf[3], A. Bodaghee[2], S. E. Boggs[4], F. Rahoui[5], V. M. Kaspi[6]

[1]Department of Astronomy, University of California-Berkeley, [2]Space Sciences Laboratory, University of California-Berkeley, [3]Columbia Astrophysics Laboratory, Columbia University, [4]Department of Physics and Space Sciences Laboratory, University of California-Berkeley, [5]Department of Astronomy and Harvard-Smithsonian Center for Astrophysics, Harvard University, [6]Physics Department, McGill University, Canada.

9:00 AM - 2:00 PM

We present preliminary results of an X-ray survey of a 2° by 0.8° region of the Norma spiral arm observed by the ACIS instrument on the Chandra X-Ray Observatory. The primary scientific goal of this survey is to find new High-Mass X-ray Binaries (HMXBs) to further our understanding of HMXB evolution, help constrain estimates of the NS/NS, NS/BH, and BH/BH binaries in the Galaxy for Advanced-LIGO studies, and probe the faint end of the HMXB luminosity function. This region was selected because hard X-ray imaging of the Galactic plane by the INTErnational Gamma-Ray Astrophysics Laboratory (INTEGRAL) showed that, after the Galactic Center, the Norma spiral arm is the region most crowded with hard X-ray sources. Furthermore, this region contains a large number of OB associations and Spitzer 8 μm images and radio maps show that it is a region of ongoing star formation, near which we would expect to find HMXBs. Our preliminary data analysis has uncovered ~1,500 X-ray sources in this field. Approximately 30 of these sources are bright, hard X-ray sources, having more than 50 counts in a 20 ks exposure, making them plausible HMXB candidates. Near-infrared imaging and spectroscopic follow-up will help us determine the true nature of these hard X-ray sources. Our Chandra survey also includes two previously identified HMXBs and at least five extended sources, one of which is a previously studied pulsar wind nebula. Our final catalog will be useful for studies of individual X-ray sources, serve as a companion and comparison to similar surveys of X-ray populations in different regions of the Galaxy, and provide identifications for hard X-ray sources found when the Nuclear Spectroscopic Telescope ARray (NuSTAR) surveys this region after its launch in early 2012.

428.18 – **The 4 Ms Chandra Deep Field-South Survey Number Counts: The Impending Dominance of Normal Galaxy Populations in Ultra-Deep X-ray Surveys**

Bret Lehmer[1]

[1]Johns Hopkins University.

9:00 AM - 2:00 PM

Through a large investment of director's discretionary time, the Chandra Deep Field-South (CDF-S) now has a total ACIS-I exposure reaching ~4 Ms in depth, making the CDF-S the deepest X-ray observation of the extragalactic Universe ever undertaken. In this poster I will present the latest estimates of the extragalactic X-ray source number counts emphasizing the nature of the sources that contribute at the faintest flux levels. We find that the majority of the 740 X-ray detected sources in the 4 Ms CDF-S are active galactic nuclei (AGNs); however, we estimate that normal galaxies, shining primarily by emission from X-ray binaries and hot gas, contribute ~40% of the total number counts above 0.5-2 keV fluxes of 8.6×10^{-18} ergs/cm^2/s. I will present a detailed break-down of the X-ray number count contributions based on a variety of source properties (e.g., AGN redshift, intrinsic column density, and X-ray luminosity and galaxy optical morphology) and implications for semi-analytic models that attempt to parameterize the SMBH accretion history and X-ray binary evolution in the Universe. I will present predictions for future X-ray surveys (e.g., via Chandra and future X-ray observatories) that probe sensitivity levels fainter than the CDF-S.

428.19 – **Panchromatic Hubble Andromeda Treasury Survey: Resolved Stellar Photometry**

Benjamin F. Williams[1], J. J. Dalcanton[1], A. E. Dolphin[2], D. Lang[3], D. Weisz[1], A. C. Seth[4], J. Kalirai[5], T. Lauer[6], K. Rosema[7]

[1]Univ. of Washington, [2]Raytheon, [3]Princeton, [4]Harvard-Smithsonian Center for Astrophysics, [5]Space Telescope Science Institute, [6]NOAO, [7]Random Walk Group.

9:00 AM - 2:00 PM

The PHAT survey is collecting photometric data with 3 cameras aboard the Hubble Space Telescope covering about one quarter of the M31 inner disk and bulge. The observing strategy allows coverage of the full survey area in 6 broad bands from the Near-UV to the Near-IR. Initial survey photometry has been performed on the data from each camera separately, then the resulting catalogs have been matched to improve astrometry and provide our first 6-band catalogs. We provide a summary of our crowding-optimized point spread function measuring technique. We present color-magnitude diagrams showing our data quality in each camera for areas of varying surface brightness in M31, and we present color-color diagrams to show the quality of our current ability to match stars across all 6 bands. These data are samples of the survey's first public data release to the Hubble data archive. Finally we present preliminary results from simultaneous photometry across all 6 bands where matching is done at the pixel level, eliminating the need for catalog matching. This new ability provides optimal depth in overlapping fields and more reliable matching of all 6 bands. Future survey data releases will include such optimized 6-band photometry. PHAT is supported by HST GO-12055 administered by NASA.

428.20 – **The First Data Release of the Catalina Surveys**

Andrew J. Drake[1], E. Beshore[2], S. G. Djorgovski[1], S. Larson[2], A. Boattini[2], M. Catelan[3], E. Christensen[4], C. Donalek[1], A. Gibbs[2], M. Graham[1], A. Grauer[2], R. Hill[2], R. Kowalski[2], A. Mahabal[1], J. L. Prieto[5], R. Williams[1]

[1]Caltech, [2]LPL, [3]PUC Catolica, Chile, [4]Gemini, Chile, [5]Princeton Uni.

9:00 AM - 2:00 PM

The Catalina Surveys consists of the Catalina Sky Survey (CSS) and the Catalina Real-time Transient Survey (CRTS). These two surveys work synergistically to extract the maximum scientific return from the data gathered by Catalina telescopes. In order to further facility the wealth of time-domain science that is possible with this data, the Catalina Surveys are now releasing Catalina Schmidt telescope photometry for ~200 million objects. Each source has been measured over a period of six years and comes from a ~24,000 square degree region between declination -30 and +70 degrees (with ~10 degree avoidance of the galactic plane). On average each location in the data release has been observed more than 200 times to a depth of V=19.5. We will provide the details of the open-access data services as well as future data releases and recent discoveries.

428.21 – **The LAMOST-PLUS Partnership: The Pilot Survey Begins**

Heidi Jo Newberg[1], Z. Bai[2], T. Beers[3], J. Carlin[1], J. Chen[2], L. Chen[4], Y. Chu[5], L. Deng[2], X. Fu[2], C. Grillmair[6], P. Guhathakurta[7], J. Hou[4], J. Hu[2], S. Lepine[8], H. Li[2], J. Li[2], C. Liu[2], X. Liu[9], A. Luo[2], H. Morrison[10], E. Peng[9], J. Sellwood[11], X. X. Xue[2], Y. Xu[2], L. Yang[9], B. Yanny[12], J. Yu[4], Y. Zhang[2], H. Zhang[2], G. Zhao[2], Y. Zhao[2], Z. Zheng[13], J. Zhong[4], Participants in LAMOST, US (PLUS), LAMOST (Guoshoujing)

[1]Rensselaer Polytechnic Inst., [2]National Astronomical Observatory of China, Beijing, China, [3]NOAO, [4]Shanghai Astronomical Observatory, China, [5]USTC, China, [6]IPAC, [7]UC Santa Cruz/ Lick Observatory, [8]American Museum of Natural History, [9]Peking University, China, [10]Case Western Reserve University, [11]Rutgers University, [12]Fermi National Accelerator Laboratory, [13]University of Utah.

9:00 AM - 2:00 PM

Participants in LAMOST, US (PLUS) has a collaborative partnership with the Galactic structure component of the Chinese LAMOST project, on the 4-meter class Guoshoujing Telescope in China. The pilot survey began in October 2011 and will use half of the available time before the summer shutdown in May 2012. The pilot survey will obtain about 1 million spectra, split between the LEGAS (extragalactic) and LEGUE (Galactic stars) portions of the survey. We present newly obtained spectra from the pilot survey. The survey of Galactic stars will collect 2.5 million faint stellar spectra and 5 million bright disk stars in a five year survey starting in 2012. US astronomers who wish to actively collaborate with the current science groups can still join. We present results from eight Chinese visiting scholars that were co-advised by Chinese and US advisors. More information can be found at http://lamost.us/. This partnership is funded by NSF grant AST-09-37523, and NSFC grants 10973015 and 11061120454.

428.22 – **Results from the NGC 7448 cube of the Arecibo Galaxy Environment Survey**

Hanna Herbst[1], R. Taylor[2], R. Minchin[2]

[1]UW Madison Astronomy Dept., [2]Arecibo Observatory, Puerto Rico.

9:00 AM - 2:00 PM

The Arecibo Galaxy Environment Survey is an ongoing neutral hydrogen galaxy survey with higher sensitivity and better spatial and velocity resolution than previous 21cm multi-beam surveys. Here, we present results from the AGES 7448 cube, a 5x4 sq deg field including the NGC 7448 galaxy group and the surrounding volume out to 19,000

km/sec. In the cube, we identify a total of 376 HI sources, including 217 new detections. A wedge plot of the detections shows clear filamentary structure throughout the volume of the cube. Within the NGC 7448 group, we detect an HI tidal bridge connecting NGC 7448 to the rest of the group members. A preliminary search for optical counterparts was performed using SDSS; of our 376 sources, we find 4 sources with early type counterparts and 12 sources with no obvious SDSS counterpart that will require follow up. Our source catalogue includes fitted positions, velocities, velocity widths, flux and HI mass measurements for each of the 376 sources.

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429 – CANDELS Poster

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

429.01 – **Host Galaxies Near And Far: The Candels Sn Survey**

Brian Hayden[1], P. Garnavich[1], CANDELS SN Survey

[1]*University of Notre Dame.*

9:00 AM - 2:00 PM

We analyze 17 host galaxies of type Ia supernovae (SN Ia) in the CANDELS supernova survey, and compare their properties to the overall properties of SN Ia host galaxies from the literature. Combined with hosts from other high redshift SN surveys, this presents a large sample of SN Ia hosts at high redshift. One goal of the CANDELS SN Survey is to discover and study type Ia supernovae at z>1 and to use them to constrain cosmological parameters. CANDELS uses the Wide Field Camera 3 (WFC3), installed on the Hubble Space Telescope in May 2009. The WFC3 near-infrared images correspond to the rest-frame optical band, which allows for higher redshift discoveries and reduces systematic errors from selection effects. We use PEGASE.2 to create simulated galactic spectral energy distributions, which are then used as templates to calculate the best-fit parameters for the CANDELS hosts. Specifically, we analyze the host galaxy mass and the star formation rate. These parameters have been shown to correlate with light curve parameters of SNe Ia, and therefore any shift in the distribution of host properties at the high redshifts in CANDELS could result in a shift in the distribution of SN Ia light curve properties. This can affect the measured cosmological parameters of our universe, especially the value of the cosmological constant and the energy density of dark energy. We compare our findings for the high redshift hosts to lower-redshift sets in the literature, and discuss our findings based on the implications for cosmology.

429.02 – **Impact of Nebular Emission on SED Fitting of CANDELS Data at $3 \leq Z \leq 7$: The SFR-Mass Relation**

Brett W. Salmon[1], C. Papovich[1], S. L. Finkelstein[2], V. Tilvi[1], CANDELS Team

[1]*Texas A&M University,* [2]*University of Texas.*

9:00 AM - 2:00 PM

We study the evolution of the relation between star-formation-rate (SFR) and stellar mass for high-redshift galaxies ($3 \leq z \leq 7$) using data from the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS). We describe a method to incorporate the effects of nebular line and continuum emission on updated stellar population synthesis models (Bruzual & Charlot 2011, in prep). We fit the multiwavelength photometry from CANDELS using these updated models over a range of stellar population parameters, including a range of star-formation histories with SFRs that both increase and decrease with time. From these fits we estimate the galaxy stellar masses and SFRs. We discuss the impact of models with nebular emission lines on the inferred stellar masses and SFRs, and we find that nebular emission lines reduce the derived stellar masses by as much as a factor of 3, in agreement with results from other studies. Using these fits, we quantify the SFR--stellar mass relation and study its evolution for galaxies at $3 \leq z \leq 7$.

429.03 – **Investigating Sub-structures Of Galaxies At z=2 With CANDELS**

Yicheng Guo[1], M. Giavalisco[1], CANDELS Team

[1]*University of Massachusetts, Amherst.*

9:00 AM - 2:00 PM

We use the deep and high-resolution optical (HST/ACS) and near--IR (HST/WFC3 IR) imaging data in the Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS) to study the sub-structure of galaxies at z~2. The CANDELS images enable us to resolve structures of z~2 galaxies down to kiloparsec scale in the rest-frame UV and optical bands. In this work, we study the properties of giant kpc-scale clumps in star-forming galaxies (SFGs) at z~2 through multi-wavelength broad band photometry. The physical properties of clumps are measured through fitting spatially resolved seven-band (BVizYJH) spectral energy distribution (SED) to models. On average, our clumps are blue and have similar median rest-frame UV--optical color as the diffuse components of their host galaxies, but the clumps have large scatter in their colors. Although the SFR--stellar mass relation of galaxies is dominated by the diffuse components, clumps emerge as regions with enhanced specific star formation rates (SSFRs), contributing individually ~10% and together ~50% of the star formation rate (SFR) of the host galaxies. However, the contributions of clumps to the rest-frame UV/optical luminosity and stellar mass are smaller, typically a few percent individually and ~20% together. Clump properties have radial variations in the sense that central clumps are redder, older, more extincted, denser, and less active on forming stars than outskirts clumps. Our results provide constraints on current theoretical models of clump formation and evolution.

429.04 – **The Assembly of Galaxies at z~2: The Emerging Diversity of Stellar Populations measured from Internal Colors with CANDELS**

Steven A. Boada[1], C. Papovich[1], S. Finkelstein[2], V. Tilvi[1], CANDELS Team

[1]*Texas A&M University,* [2]*The University of Texas at Austin.*

9:00 AM - 2:00 PM

We study the internal UV-optical colors of galaxies at $1.5 < z < 3.5$ using HST ACS and WFC3 images from CANDELS in the GOODS-S and HUDF fields. The internal color dispersion quantifies spatial differences in the stellar populations within a galaxy. We find that the internal color dispersion between bands that probe the rest-frame UV quantifies primarily differences in dust extinction, while internal UV-optical color dispersion constraints the amount of current star-formation to older stellar populations. We study trends in the internal color dispersion with other galactic properties such as mass, total color, and size, in order to study the relation between galaxy growth and their star formation histories. We find that for galaxies at $1.5 < z < 3.5$ the internal color dispersion increases both with stellar mass and galaxy size. It remains low for low-mass galaxies and increases as the mass increases up to galaxies with stellar masses $\sim 10^{11}$ solar masses. Therefore, the process of increasing the heterogeneity of a galaxy's stellar populations (as measured by the internal color dispersion) is related to the process of galaxy build-up.

429.05 – **Candels Observations Of The Relation Between Galaxy Color, Stellar Mass, And Morphology With Environment At Z=1.6**

Robert Bassett[1], C. J. Papovich[1], J. M. Lotz[2], K. Tran[1], S. Finkelstein[3], H. Ferguson[2]

[1]*Texas A&M University,* [2]*STSI,* [3]*University of Texas.*

9:00 AM - 2:00 PM

We study the relationship between color, stellar mass, morphology, and environment for a sample of galaxies at $z = 1.6$ selected from the CANDELS data in the UKIDSS Ultradeep Survey. For each galaxy in this sample, we quantify the morphology using the Sersic index as measured by GALFIT from the WFC3 F125W images. We quantify the environment using the projected distance to the 7th nearest neighbor, d7. Several trends appear between color, mass, Sersic index, and environment. Compared to galaxies in low density regions, bulge dominated ($n > 2$) galaxies in high density regions ($d7 < 0.7$ Mpc) lie almost exclusively on the red sequence: there are very few star-forming, bulge dominated galaxies in high density regions. Furthermore, we find a lack of low mass ($M < 3 \times 10^{10}$ $M\odot$), bulge-dominated red-sequence galaxies in the low-density regions, while these are clearly present in the high density regions. We explore these trends further by selecting only the quiescent galaxies using a color-color selection. We find that quiescent galaxies in the high density regions are nearly all bulge dominated (only 3/23 galaxies, are apparently disk dominated with $n < 2$). In contrast, in the low density regions roughly 20% of the quiescent galaxies are disk dominated. These results provide evidence that galaxies in high density regions experience accelerated assembly histories, which both accelerates morphological evolution (faster transition to bulge-dominated galaxies) and may also cause faster cessation of star formation, producing more low mass red galaxies.

429.06 – **No Significant Evolution in the Bar Fraction in Large Disk Galaxies From z=1.8 to z=0.6**

Jessica Herrington[1], E. Bell[1], CANDELS Team

[1]*University of Michigan.*

9:00 AM - 2:00 PM

We use HST/WFC3 images from the CANDELS survey of GOODS-S and UDS to determine the evolution of the bar fraction of disk galaxies between redshifts 0.6 and 1.8. We include galaxies with masses between 1.6e10 and 1e11, redshifts between 0.6 and 2.2, H band apparent magnitude less than 24, Sersic index less than 3.5, ellipticity less than 0.5, and effective radius greater than 0.42". We classify the sample visually to determine the morphology of each galaxy and if it has a bar. We find the completeness of our sample at $z > 1$ by artificially redshifting galaxies with $z < 1$ to $1 < z < 2.2$. We find the bar fraction to be constant within error bars between redshifts 0.6 and 1.8.

429.07 – **Candels: GOODS-S1 And GOODS-S2 Strong Lens Candidates.**

Alexander Chiu[1], H. Fu[1], J. Calanog[1], A. Cooray[1], J. Wardlow[1], CANDELS team

[1]*University of California - Irvine.*

9:00 AM - 2:00 PM

We present gravitationally lensed candidates from the Hubble Space Telescope (HST)/Wide Field Camara-3 (WFC3) images of the Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS). In the early imaging data, we find two candidates in the GOODS-S field. GOODS-S1 is newly discovered while GOODS-S2 was previously proposed in a previous lens candidate paper (More et al, 2011). GOODS-S1 has a foreground photometric redshift of 1.135 while GOODS-S2 has a spectroscopic redshift of 1.02. The candidates were modeled, using CANDELS WFC3 data, as compact Einstein ring systems. From our models, we have GOODS-S1 with an Einstein radius of about 0.54 arcseconds with a magnification factor of approximately 100 while GOODS-S2 has an Einstein radius of about 0.5 arcseconds with a magnification factor of approximately 20. More lens candidates will be studied and presented as CANDELS coverage on the sky expands to other fields.

429.08 – **Color Gradients of Passive Disks at z~2**

Elizabeth J. McGrath[1], A. van der Wel[2], D. C. Koo[1], S. M. Faber[1], M. Mozena[1], S. Wuyts[3], Y. Guo[4], CANDELS team

[1]*University of California, Santa Cruz,* [2]*MPIA, Germany,* [3]*MPE, Germany,* [4]*University of Massachusetts, Amherst.*

9:00 AM - 2:00 PM

Recent studies have revealed a population of massive disk galaxies at high-redshift that appear to be comprised entirely of old stars. Commonly proposed mechanisms for quenching star formation in massive galaxies, such as major mergers and AGN feedback, typically result in bulge-dominated systems or at least significant bulge components. Indeed in the local Universe, massive, quiescent systems are almost entirely spheroidal in shape, while star forming systems are more disk-like. It would appear that the processes governing star-formation quenching and morphological transition are closely linked, and passive disk galaxies at high-z may provide evidence of an important transition population. In order to better understand how passive disks compare to similarly quiescent spheroidal systems as well as star-forming disks at the same redshift, we examine their color gradients and structural properties using deep, high-resolution imaging data from the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS). While there are important structural differences between passive disks and their star-forming counterparts, we find that their radial color gradients imply a distribution of stellar populations that are much more similar to the quiescent spheroids, suggesting that whatever mechanism is responsible for quenching star-formation occurs in advance of their final morphological transition.

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430 – Computation and Data Handling

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

430.01 – **Cyber Exploration of the Interstellar Medium: A New Age of Broadband Data Cube Analysis**

Brent J. Harris[1], B. Pate[1], K. Lehmann[1], T. Remijan[2], C. Brogan[2], Virginia Image and Video Analysis

[1]*University of Virginia,* [2]*National Radio Astronomy Observatory.*

9:00 AM - 2:00 PM

A new method of visualizing large data cubes has been implemented. Visualizing the cube in "correlation space," where spatial distribution is exploited for statistical connection between data channels, is an effective tool for screening co-spatial features and dumping feature-less pixels out of the data set. The technique was showcased on the Expanded Very Large Array Demonstration Science data of Orion KL in the 23.6 GHz to 26.6 GHz spectral range. Along a particular line of sight, both thermalized and non-thermalized methanol is present in Orion KL, and the spectra can be separately analyzed. The thermalized methanol, unseen in the methanol map (and unapparent in the 1D spectrum), belongs to the hot core and is measured to have a rotational temperature of 118K and a gas density above 10^7 cm^{-3}. The non-thermal methanol emission profiles vary throughout the cloud, and each spectrum can be reproduced using a steady-state, LVG model adapted for integration into this study. The spectrum is then used as a densitometer and thermometer for each pixel in order to construct morphology. The implications of the results include new and powerful solutions to problems in large data analysis. They also challenge current practice. Conventional Gaussian fitting to resolve sources, already implemented in Orion hot core studies is unsuitable without a correlation analysis of all channels that fall in the emission/absorption features. This is also the first study to model broadband methanol masing in a star forming region as a means to visualize maps of temperature and density morphology. The techniques used to obtain the results utilize modest computing resources and can be automated for use by a diverse group of users.

430.02 – **IMCOM:A Method for the Optimized Linear Combination of Astrophysical Images**

Jason Rhodes[1], B. Rowe[1], C. Hirata[2], S. Seshadri[1], R. Smith[2]

[1]*JPL,* [2]*Caltech.*

9:00 AM - 2:00 PM

We demonstrate a simple, yet general, new formalism for the optimized linear combination of astrophysical images. The formalism allows the user to combine multiple undersampled images to provide oversampled output at high precision. The proposed method is general and may be used for any configuration of input pixels and point spread function; it also provides the noise covariance in the output image along with a powerful metric for undesired distortions due to the linear image combination. The method explicitly provides knowledge and control of the inevitable compromise between noise and fidelity in the output image. In this poster we present a first implementation of the method called IMCOM, which has been put to practical use in demonstrating the recovery of fully-sampled output images from simulated, undersampled input exposures that are designed to mimic the proposed Wide Field InfraRed Survey Telescope (WFIRST). We also show early results from a first study using IMCOM with real data from a laboratory detector characterization experiment at the Caltech Optical Observatories facility, which will use the ability of IMCOM to resample a heavily undersampled focal plane to explore the small-scale structure of detectors for use in a dark energy mission.

430.03 – **Imtrandetect: A New Tool/methodology For Detecting Astronomical Transients From Large Image-data Streams**

Frank J. Masci[1], D. Hoffman[1]

[1]*IPAC/Caltech.*

9:00 AM - 2:00 PM

One of the challenges in current and future time-domain surveys is to identify reliable candidate transient and variable sources for further follow-up and classification (if possible). We describe a new methodology for optimally detecting transients from multi-epoch image data, with an emphasis on minimizing contamination from instrumental artifacts and glitches. The method is based on collapsing prior-masked image stacks into various metric-statistic images for later thresholding and object detection. The stacking is performed in moving windows along the time-ordered image sequence where window lengths are tuned to maximize the sensitivity of the metrics for detecting intermittent local transient behavior above the baseline noise traced by the full time-series of each pixel signal. We show example light curves generated by the tool, from testing on image data containing known transients and variables from the Catalina Real-time Transient Survey (CRTS) and the Wide-field Infrared Survey Explorer (WISE). We also show the light curves of some new interesting candidate transients and variables found in these test fields.

430.04 – **High Energy Astronomical Data Processing and Analysis via the Internet**

Lynne A. Valencic[1], S. Snowden[2], W. Pence[2]

[1]*Johns Hopkins Univ.,* [2]*NASA-GSFC.*

9:00 AM - 2:00 PM

The HEASARC at NASA Goddard Space Flight Center and the US XMM-Newton GOF has developed Hera, a data processing facility for analyzing high energy astronomical data over the internet. Hera provides all the disk space and computing resources needed to do general processing of and advanced research on publicly available data from High Energy Astrophysics missions. The data and data products are kept on a server at GSFC and can be downloaded to a user's local machine. Further, the XMM-GOF has developed scripts to streamline XMM data reduction. These are available through Hera, and can also be downloaded to a user's local machine. These are free services provided to students, educators, and researchers for educational and research purposes.

430.05 – **Data Wrangling Within Different Astronomy Career Trajectories**

Reynal Guillen[1], D. Gu[1], J. Holbrook[1], L. Murillo[1], S. Traweek[1]

[1]*University of California, Los Angeles.*

9:00 AM - 2:00 PM

Five kinds of astronomers work with large data sets: cosmologists, data analysts, instrumentation people, observers, and numerical theorists. Each of these career trajectories can diverge and converge in and out of collaborations with each other and perform different kinds of work. Nonetheless, each group defines and wrangles data differently. This poster characterizes their different meanings of data, analytic skills, techniques, and technologies. It also identifies some sites and patterns of convergence. We plot these collaborative relationships in bi-partite graphs. These emergent characteristics of the astronomy workforce have implications for curricula, pedagogies, and the division of labor in research collaborations.

430.06 – **Mining the Green Bank Telescope Metadata Archive: Statistics on Radio Frequency Use, 2002-2011**

Michael Blatnik[1], A. W. Clegg[2], C. Beaudet[3], R. J. Madellena[3]

[1]*University of Massachusetts Amherst,* [2]*National Science Foundation,* [3]*National Radio Astronomy Observatory.*
9:00 AM - 2:00 PM

The purpose of our project was to extract metadata from the Green Bank Telescope archives to create histograms of frequencies observed vs. time observed within a frequency. To do this, we created programs that could retrieve the data out of the FITS storage files and into a readable data file. Besides creating usage histograms, we also looked at how much observing occurred within astronomy-allocated bands, and found that 21% of the observing occurred entirely within an allocated band while 56% of observing occurred at least partially within an allocation. We were able to account for the large majority of the data including the non-standard backends. We were able to see general observing trends, including how much observing occurs within astronomy-allocated bands. By better understanding what frequencies astronomers use, we can better gauge what frequencies need more protection.

431 – Education & Outreach

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

431.01 – **Public Outreach at Appalachian State University's Dark Sky Observatory Cline Visitor Center**

Daniel B. Caton[1], L. Hawkins[1], A. B. Smith[1]

[1]*Appalachian State Univ..*
9:00 AM - 2:00 PM

With the recent completion of the Cline Visitor Center we have begun a program of public nights at our Dark Sky Observatory's 32-inch telescope. Events are ticketed online using an inexpensive commercial ticketing service and are limited to two groups of 60 visitors per night that arrive for 1.5-hour sessions. We are installing two large (70-inch) flat panel displays in the Center and planning additional exhibits to entertain visitors while they await their turn at the telescope's eyepiece. The facility is fully ADA compliant, with eyepiece access via a DFM Engineering Articulated Relay Eyepiece, and a wheelchair lift if needed. We present some of our experiences in this poster and encourage readers to offer suggestions.

The Visitor Center was established with the support of Mr. J. Donald Cline, for which we are very grateful. The telescope was partially funded by the National Science Foundation.

431.02 – **2011 Astronomy Day at McDonald Observatory**

Sandra Preston[1], M. Hemeway[1], M. Wetzel[1]

[1]*The University of Texas at Austin.*
9:00 AM - 2:00 PM

Our philosophy is that everyday is Astronomy Day because the McDonald Observatory's Frank N. Bash Visitors Center is open 362 days a year. So, how did we create a special celebration for the "Astronomy Day" declared by the Astronomical League?

During September 26-29 we conducted 20 videoconferences and served 12,559 students with "Astronomy Day" programming. Connect2Texas provides bridging for a network of Texas-based museums and cultural, historical, and scientific organizations that offer educational content to schools throughout the state via videoconferencing. Connect2Texas connected McDonald Observatory to 334 schools; most of these schools were in Texas, but schools in a dozen other states also participated. While most schools had a "view-only" connection, at least 20 of the schools had interactive connections, whereby the students could ask questions of the presenter. Connect2Texas also collects evaluation information from the participating schools that we will use to produce a report for our funders and make modifications to future programs as need be. The videoconferences were offered free of charge.

The theme for the 2011 Astronomy Day program was the Year of the Solar System, which aligns with NASA's theme for 2011 and 2012. By aligning with this NASA theme, we could leverage NASA artwork and materials to both advertise and enrich the learning experience. Videoconference materials also included pre- and post-videoconference assessment sheets, an inquiry based activity, and pre- and post-videoconference activities, all of which were made available online.

One of the lessons learned from past Astronomy Day videoconferences is that the days the Astronomical League declares as "Astronomy Day" are not always good days for Texas schools to participate. So, we choose an Astronomy Day that meets the needs of Texas schools and our schedule—so any day can be Astronomy Day.

2011 Astronomy Day was made possible by The Meyer-Levy Charitable Trust.

431.03 – **Black Holes Traveling Exhibition: This Time, It's Personal.**

Mary E. Dussault[1], E. L. Braswell[1], S. Sunbury[1], M. Wasser[1], R. R. Gould[1]

[1]*Harvard-Smithsonian, CfA.*
9:00 AM - 2:00 PM

How can you make a topic as abstract as black holes seem relevant to the life of the average museum visitor? In 2009, the Harvard-Smithsonian Center for Astrophysics developed a 2500 square foot interactive museum exhibition, "Black Holes: Space Warps & Time Twists," with funding from the National Science Foundation and NASA. The exhibition has been visited by more than a quarter million museum-goers, and is about to open in its sixth venue at the Reuben H. Fleet Science Center in San Diego, California. We have found that encouraging visitors to adopt a custom black hole explorer's identity can help to make the science of black holes more accessible and meaningful. The Black Holes exhibition uses networked exhibit technology that serves to personalize the visitor experience, to support learning over time including beyond the gallery, and to provide a rich quantitative source of embedded evaluation data. Visitors entering the exhibition create their own bar-coded "Black Holes Explorer's Card" which they use throughout the exhibition to collect and record images, movies, their own predictions and conclusions, and other black hole artifacts. This digital database of personal discoveries grows as visitors navigate through the gallery, and an automated web-content authoring system creates a personalized online journal of their experience that they can access once they get home. We report here on new intriguing results gathered from data generated by 112,000 visitors across five different venues. For example, an initial review of the data reveals correlations between visitors' black hole explorer identity choices and their engagement with the exhibition. We will also discuss correlations between learning gains and personalization.

431.04 – **International Astronomical Search Collaboration -- Astronomical Discovery Program for High School and College Students**

Patrick Miller[1]

[1]*Hardin-Simmons University.*
9:00 AM - 2:00 PM

Centered at Hardin-Simmons University (Abilene, TX) the

International Astronomical Search Collaboration (IASC) has conducted successful student-based asteroid search programs, called campaigns. Since 2006 these campaigns have engaged 3,000 high school and college students per year. These students come from 300 schools worldwide located in more than 40 countries on 5 continents. Students have made thousands of observations of near-Earth objects and >300 provisional discoveries of Main Belt asteroids, both reported to the Minor Planet Center (Harvard). To date students have 15 numbered discoveries, catalogued by the IAU and currently being named by the student discoverers.

The first telescope of the Panoramic Survey and Rapid Response

System (PS1, University of Hawaii) is conducting the largest optical survey ever attempted. In support of education and public outreach, Pan-STARRS collaborated with IASC in 2010-2012 to use the PS1 images in the student asteroid search and discovery campaigns.

The PS1 images are wide field with 7^{o} FOV and 1.4 Gpix in size. These were partitioned into 144 sub-images and distributed to 40 high schools in Texas, Hawaii, Washington, Germany, Taiwan, Poland, Brazil, and Bulgaria. In two 6-week campaigns per year, students from these schools made ~1000 preliminary asteroid discoveries.

This poster presents the results of the first and second year of the IASC-PS1 campaigns plus other asteroid search campaigns conducted by IASC. Also, plans will be described for future campaigns. These future campaigns will reach 500 schools in 2012 and 1,000 high schools within the coming 36 months.

431.05 – **WWT Ambassadors: Worldwide Telescope For Interactive Learning**

Patricia S. Udomprasert[1], A. A. Goodman[1], C. Wong[2]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*Microsoft Research.*
9:00 AM - 2:00 PM

WorldWide Telescope (WWT) offers an unparalleled view of the world's store of online astronomical data. This free software weaves astronomical images from all wavelengths into an interface that resembles their natural context-the Sky-while offering deep opportunities to teach and learn the science behind the images. The WorldWide Telescope Ambassadors Program (WWTA) is an outreach initiative run by researchers at Harvard University and Microsoft Research. WWT Ambassadors are experts on Astronomy and Physics who use WWT to educate the public about astronomy and science. Ambassadors and learners alike use WWT to create dynamic, interactive Tours of the Universe, which are shared in schools, public venues, and online. Ambassador-created Tours are being made freely available and will ultimately form a comprehensive learning resource for Astronomy and Astrophysics.

In this poster, we present summary results of WWTA's work in 6th-grade classrooms, reaching 400 students over the past 2 years. The WWTA Pilot compared learning outcomes for 80 students who participated in WWTA and 70 students at the same school and grade who only used traditional learning materials. After the six-week unit, twice as many "WWT" as "non-WWT" students understand complex three dimensional orbital relationships; and tremendous gains are seen in student interest in science overall,

and astronomy in particular. In anonymous written surveys, 90% of the 6th-graders described WWT as “awesome,” “cool,” or “a fun way to learn science,” and said they would recommend WWT to their best friend.

We outline new plans to develop and field-test WWT-based interactive visualization labs that teach students standards-based middle school space science topics, and we describe the development of an online community that serves as a resource for Ambassadors, teachers, and students across the US and beyond.

Learn more about WWTA at:

wwtambassadors.org

431.06 – **Astronomy Student Activities Using Stellarium Software**

Raymond D. Benge[1], S. R. Tuttle[1]

[1]*Tarrant County College.*

9:00 AM - 2:00 PM

Planetarium programs can be used to provide a valuable learning experience for introductory astronomy students. Educational activities can be designed to utilize the capabilities of the software to display the sky, coordinates, motions in the sky, etc., in order to learn basic astronomical concepts. Most of the major textbook publishers have an option of bundling planetarium software and even laboratory activities using such software with textbooks. However, commercial planetarium software often is updated on a different schedule from the textbook revision and new edition schedule. The software updates also sometimes occur out of sync with college textbook adoption deadlines. Changes in software and activity curriculum often translate into increases costs for students and the college.

To provide stability to the process, faculty at Tarrant County College have developed a set of laboratory exercises, entitled Distant Nature, using free open source Stellarium software. Stellarium is a simple, yet powerful, program that is available in formats that run on a variety of operating systems (Windows, Apple, linux). A web site was developed for the Distant Nature activities having a set version of Stellarium that students can download and install on their own computers. Also on the web site, students can access the instructions and worksheets associated with the various Stellarium based activities. A variety of activities are available to support two semesters of introductory astronomy.

The Distant Nature web site has been used for one year with Tarrant County College astronomy students and is now available for use by other institutions. The Distant Nature web site is http://www.stuttle1.com/DN_Astro/index.html .

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432 – The Sun, The Solar System and Extrasolar Planets

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

432.01 – **On The Neutral ISM In The Kepler Field Of View: Using Spectroscopy To Map The Distribution Of NaI**

Kathryn Silverio[1]

[1]*University of California, Berkeley.*

9:00 AM - 2:00 PM

I’m currently working to build a high-resolution map of the interstellar medium within the Kepler field. All Kepler Objects of Interest are being observed spectroscopically, both for confirmation of planet detection by radial velocity and to characterize the star. In some of the HIRES spectra of Kepler stars, absorption lines from interstellar clouds are clearly visible. In particular, the sodium D doublet, a 3p to 3s transition in neutral sodium split due to spin-orbit coupling, is apparent. The Na D lines have a very high Einstein A coefficient, and thus make it easy to observe and quantify columns of neutral sodium in the ISM. Since neutral sodium is a good tracer of the neutral ISM, Na D observations are used by the ISM community to estimate column densities of HI and map the neutral ISM. My task is to build a pipeline that identifies clouds along the sightline to each star and determines their velocities and the column density of sodium in each. Sodium D absorption has also proved useful to the supernova community. Dust columns are correlated with neutral hydrogen, so Na D absorption should be a proxy for extinction. Often, the extinction on the line-of-sight to a supernova is unknown and thus we can’t determine the true, unreddened color of the supernova. Na D absorption and reddening laws are therefore used to estimate the true colors of supernovae. However, this method has been called into question recently when the correlation between Na D columns toward Type Ia supernovae and extinction was shown to be tenuous. These Na D columns, which are not at risk of being contaminated with galactic light like the columns to supernovae, can be used to check again whether a Na D-extinction correlation exists.

432.02 – **A Subaru SEEDS Imaging Search for Extrasolar Planets Around Early-Type Stars**

Joseph Carson[1], C. Thalmann[2], M. Janson[3], T. Kozakis[1], P. Wong[1], M. Goto[4], T. Henning[4], W. Brandner[4], B. Biller[4], M. Bonnefoy[4], M. Feldt[4], M. McElwain[5], R. Kandori[6], M. Tamura[6], SEEDS Team

[1]*College of Charleston,* [2]*Anton Pannekoek Astronomical Institute, Netherlands,* [3]*Princeton University,* [4]*Max Planck Institute for Astronomy, Germany,* [5]*NASA Goddard Space Flight Center,* [6]*National Astronomical Observatory of Japan, Japan.*

9:00 AM - 2:00 PM

We present a status report on the Subaru SEEDS sub-program to search for extra-solar planets around early-type (mostly A-type) stars. SEEDS, the Strategic Exploration of Exoplanets and Disks with Subaru, is a multi-year, direct-imaging survey to explore the link between planets and disks, and the evolution of protoplanetary systems and debris disks. With first observations carried out in 2009, the high-mass star sub-program uses the Subaru 8-meter Telescope, a 188 actuator curvature AO system (AO188), and a near infrared imaging science camera (HiCIAO) to search for exoplanet signatures. We describe the early-type star target sample, science goals, observing procedures, and early results.

432.03 – **Towards Earth-like Worlds: Identifying and Removing Stellar Jitter**

Heather M. Cegla[1], C. Watson[2], T. Marsh[3], S. Shelyag[2], V. Moulds[2], S. Littlefair[4], M. Mathioudakis[2], D. Pollacco[2], X. Bonfils[5]

[1]*Queen's University Belfast, United Kingdom; Vanderbilt University,* [2]*Queen's University Belfast, United Kingdom,* [3]*University of Warwick, United Kingdom,* [4]*University of Sheffield, United Kingdom,* [5]*Universit J. Fourier/CNRS, Laboratoire dAstrophysique de Grenoble, France.*

9:00 AM - 2:00 PM

Space-based, photometric surveys have moved us into a new era of exoplanet discovery. In order to confirm the masses and hence the planetary nature of exoplanet candidates from such surveys, radial velocity (RV) follow up is mandatory. To do this for low-mass planets typically requires cm/s RV precision. However, astrophysical noise sources (or stellar jitter) due to spots, plages, granulation and stellar oscillations, for example, become an issue at the m/s level. These phenomena alter the shape of the stellar absorption lines, injecting spurious or systematic RV signals that may mask or mimic planetary signals. As such, ‘quiet’ stars (those with little activity) are the most likely candidates for the detection of low-mass planets, but even these stars will still exhibit some stellar jitter. We present our techniques to explore the stellar jitter due to granulation through the use of sophisticated 3D magnetohydrodynamical simulations of the Sun. In addition, we also present the identification of an entirely new source of stellar jitter that has been hitherto unrecognized and that could impact the RV follow-up and confirmation of low-mass terrestrial planets and Earth-like worlds.

432.04 – **The McDonald Observatory Planet Search: New Long-Periodic Giant Planets, and Two Interacting Jupiters in the HD 155358 System**

Paul Robertson[1], M. Endl[2], W. D. Cochran[2], P. J. MacQueen[2], R. A. Wittenmyer[3], J. Horner[3], E. J. Brugamyer[1], A. E. Simon[4], S. I. Barnes[2], C. Caldwell[1]

[1]*University of Texas at Austin,* [2]*McDonald Observatory / University of Texas at Austin,* [3]*University of New South Wales, Australia,* [4]*Konkoly Observatory of the Hungarian Academy of Sciences, Hungary.*

9:00 AM - 2:00 PM

We present high-precision radial velocity (RV) observations of four solar-type (F7-G5) stars -- HD 79498, HD 155358, HD 197037, and HD 220773 -- taken as part of the McDonald Observatory Planet Search Program. For each of these stars, we see evidence of Keplerian motion caused by the presence of one or more gas giant planets in long-period orbits. We derive orbital parameters for each system, and note the properties (composition, activity, etc.) of the host stars. While we have previously announced the two-gas-giant HD 155358 system, we now report a shorter period for planet c. This new period is consistent with the planets being trapped in mutual 2:1 mean-motion resonance. We therefore perform an in-depth stability analysis, placing additional constraints on the orbital parameters of the planets. These results demonstrate the excellent long-term RV stability of the spectrometers on both the Harlan J. Smith 2.7 m telescope and the Hobby-Eberly telescope.

432.05 – **Probable z'-band Ground-based Detection of the Secondary Eclipse of WASP-19b**

John Burton[1], C. A. Watson[1], S. P. Littlefair[2]

[1]*Queen's University Belfast, United Kingdom,* [2]*University of Sheffield, United Kingdom.*

9:00 AM - 2:00 PM

We present the probable ground-based detection of the secondary eclipse of the transiting exoplanet WASP-19b. The observations were made in the Sloan z'-band using the ULTRACAM triple-beam CCD camera mounted on the NTT. The measurement shows a 1±0.2mmag eclipse depth, consistent with a dayside temperature of ~2900K,

matching previous predictions based on H- and K-band measurements. However, since this is based on a single observation, the eclipse depth - at the moment - is not particularly well constrained, and would benefit from additional observations at similar wavelengths. Our technique for the data reduction and analysis is described, along with our approach to dealing with systematic errors associated with ground-based secondary eclipse observations.

432.06 – **The TERMS Project: Improved Orbital Parameters and Photometry of HD168443 and the Photometry Pipeline**

Genady Pilyavsky[1], S. Mahadevan[1], S. R. Kane[2], A. W. Howard[3], D. R. Ciardi[2], C. de Pree[4], D. Dragomir[2], D. Fischer[5], G. W. Henry[6], E. L. N. Jensen[7], G. Laughlin[3], H. Marlowe[4], M. Rabus[8], K. von Braun[2], J. T. Wright[1], X. Wang[1]

[1]Pennsylvania State University, [2]Caltech, [3]University of California, [4]Agnes Scott College, [5]Yale University, [6]Tennessee State University, [7]Swarthmore College, [8]Pontificia Universidad Catolica de Chile, Chile.

9:00 AM - 2:00 PM

The discovery of transiting planets around bright stars holds the potential to greatly enhance our understanding of planetary atmospheres. The Transit Ephemeris Refinement and Monitoring Survey (TERMS) project focuses on updating the ephemerides of known exoplanets, put tighter constraints on the orbital parameters and shrink the large errors on the predicted transit windows, enabling photometric monitoring to search for a transit signature.

Here, we present the revised orbital parameters and the photometric coverage during a predicted transit window of HD168443b, a massive planet orbiting the bright star HD 168443 (V = 6.92) with a period of 58.11 days. The high eccentricity of the planetary orbit (e = 0.53) significantly enhances the a-priori transit probability (3.7%) from what is expected for a circular orbit (2.5%). The transit ephemeris was updated using refined orbital parameters from additional Keck-HIRES radial velocities. The photometry obtained at the 1 m telescope in Cerro Tololo Inter-American Observatory (CTIO) and the T8 0.8 m Automated Photometric Telescope (APT) at Fairborn Observatory achieved the necessary millimag precision. The expected change in flux (0.5%) for HD168443 was not observed during the predicted transit window, thus allowing us to rule out the transit and put tighter constrains on the orbital inclination of HD168443b.

Additionally, we present the software used to analyze the CTIO data. Developed by the TERMS team, this IDL based package is a fast, precise, and easy to use program which has eliminated the need for external software and command line prompts by utilizing the functionality of a graphical user interface (GUI).

432.07 – **The Planet-Metallicity Correlation in the Kepler Field**

Keith Hawkins[1], J. Johnson[2], T. Morton[2]

[1]Ohio University, [2]Caltech.

9:00 AM - 2:00 PM

One of the most interesting correlations that has come out of large statistical studies of exoplanets is a relationship between the occurrence rate of giant planets and the metallicity of their host stars. The primary goal of this project is to develop an automated pipeline to measure stellar parameters (e.g. effective temperature, surface gravity and metallicity) of a large number of stars. We use a spectral index-based method that employs a Bayesian approach to determine the stellar parameters of stars. Results will be presented. This method will be applied to a large number of target stars in the Kepler field in order to determine the nature of the planet-metallicity correlation for small planets for the first time.

432.08 – **Detection of Exoplanet Thermal Emission with Future High-Resolution Spectrometers**

Kevin Gullikson[1], M. Endl[1], D. Jaffe[1]

[1]University of Texas Austin.

9:00 AM - 2:00 PM

Detection of planetary atmospheres is an important step in constraining models of their formation as well as current state. All atmospheres spectroscopically detected to date have been those of transiting exoplanets, either by observing the transmission spectrum during transit or the thermal emission out of transit. The latter has so far mostly been done with low to medium resolution spectroscopy from space using Spitzer or HST. With high-resolution spectroscopy of the planet's thermal emission, the radial velocity of a planet can be determined. Combining this with the stellar radial velocity can give the true mass of the planet, even for non-transiting planets. Since most planets are not transiting, this technique could be used to improve statistics on the true mass distribution of exoplanets and be used to improve planetary formation models. Here we present simulated data taken using the future near-IR instruments IGRINS and GMTNIRS, and show their ability to detect planetary atmospheres and determine their inclination and true mass. We develop a technique that can effectively remove the stellar spectrum from SNR > 200 observations of a system, by utilizing the motion of the planetary lines relative to the stellar lines at different phases of the planet's orbit. We find that these two instruments, and any other future instruments like them, should be able to detect a planetary atmosphere and measure the true mass of a planet. We acknowledge the University of Texas at Austin for support in this project.

432.09 – **Searching for Sunquakes in Solar Cycle 24**

Karen Garcia[1], T. Barajas[1], D. Vo[1], N. Murphy[2]

[1]California State University Los Angeles, [2]Jet Propulsion Laboratory.

9:00 AM - 2:00 PM

While the most visible aspects of solar flares are energetic outbursts of extreme ultraviolet, x-ray and gamma ray radiation, they also produce signatures in the photosphere, seen in velocity data as circular wave fronts expanding from the flare site (Kosovichev and Zharkova, 1998). These sunquakes are rare, and are often not seen even in response to X class flares. We report on a search for sunquakes using Doppler imaging data collected in the early part of solar cycle 24, using a prototype compact Doppler-magnetograph in the JPL Solar/Magnetic lab.

432.10 – **Io's Eclipse Emission Spectrum Following Umbral Ingress**

Laurence M. Trafton[1], C. H. Moore[2], D. B. Goldstein[1], P. L. Varghese[1], M. A. McGrath[3]

[1]Univ. of Texas at Austin, [2]Sandia National Laboratories, [3]NASA's MSFC.

9:00 AM - 2:00 PM

HST/STIS observations of Io obtained in Aug 1999 shortly after umbral ingress into Jupiter's shadow reveal a mid-UV to visual emission spectrum of SO_2 excited by impact from Jovian plasma torus electrons (illumination of Io by sunlight refracted by Jupiter's atmosphere is negligible). This spectrum peaks near 3200 Å at 27 Rayleighs/Å. The excitation-dissociation byproducts SO, S I, O I, and potentially S_2, are also observed to emit over this range. Two tandem 12-13 min mid-UV exposures obtained with the STIS/MAMA detector beginning 1 min after umbral ingress showed significant weakening of the emission spectrum, which we attribute to partial freezing out of the atmospheric column and the loss of energetic photo-electrons. Similar exposures obtained in the near-UV to visual wavelength range with the STIS/CCD detector beginning 13 min after umbral ingress showed little change in the emission intensity, indicating that most of the freezeout had already occurred. With several minutes between exposures, this time scale is consistent with Io's eclipse light curve taken with the Cassini ISS camera through the clear filter (mid-UV to near-IR), which showed a decline in the disk-averaged intensity in the first 18 min, a relatively flat plateau, then a rise to the pre-eclipse level just prior to egress (Geissler et al. 2004). An unidentified emission source is needed to explain the emission observed longward of the SO_2 emission. The low signal level required binning of pixels resulting in only a few spatial resolution elements over Io's disk. Specific plume activity is not well constrained through examination of the disk-averaged MUV emission spectrum. The simulated best fit upstream electron temperature accounting for the peak SO/ SO_2 intensity ratios and the absolute intensities is a thermal temperature of 4-5 eV and a non-thermal 30 eV electron density that is 2--5% of the thermal density.

432.11 – **Radar Observations of 2005 YU55's Flyby of Earth**

Patrick A. Taylor[1], M. C. Nolan[1], E. S. Howell[1], M. W. Busch[2], L. A. M. Benner[3], M. Brozovic[3], J. D. Giorgini[3], J. S. Jao[3], C. G. Lee[3], M. A. Slade[3], F. D. Ghigo[4], J. L. Margot[2]

[1]Arecibo Observatory, [2]UCLA, [3]Jet Propulsion Laboratory, [4]NRAO/Green Bank.

9:00 AM - 2:00 PM

Arecibo S-band (2380-MHz, 13-cm) radar observations in April 2010 determined that near-Earth asteroid 2005 YU55 is a dark, spherical object about 400 meters in diameter with a slow rotation period of roughly 18 hours. Radar astrometry provided by Arecibo during the 2010 apparition substantially improved the orbit of 2005 YU55, eliminating it as a potential Earth impactor in the near future and predicting the proximity of the November 2011 flyby, which, at a minimum of 0.85 lunar distances, was the closest known flyby of Earth by an object this size in the last 35 years. Such a close flyby provided an extraordinarily strong radar target and an invaluable scientific opportunity. Thus, a comprehensive radar observing campaign for 2005 YU55 was undertaken that utilized the Arecibo S-band and Goldstone X-band (8560-MHz, 3.5-cm) radar systems as well as the Green Bank Telescope and elements of the Very Long Baseline Array. Radar observations during the November 2011 flyby allowed for finer range and frequency resolution than the April 2010 observations by Arecibo alone and, therefore, will refine the size, shape, spin, surface and reflection properties, future trajectory, and impact hazard assessment of 2005 YU55.

432.12 – **A Reevaluation of the Hubble Space Telescope Spectra of the Impact of the LCROSS Satellite with the Moon**

Alex Storrs[1], L. Guillou[1]

[1]Towson Univ..

9:00 AM - 2:00 PM

We present Hubble Space Telescope (HST) NUV spectra of the near lunar region at the time of the impact of the LCROSS experiment into a permanently shadowed crater on the lunar south pole (Colaprete 2007). Spectra show persistent emission features in

the 270-300 nm wavelength region, which indicate a permanent lunar exosphere of metal ions, rather than OH produced by photolysis of water liberated by the impact event. Analysis of the data is limited by uncertainty in the HST pointing, as the observations were made under gyro control, and by the intrinsic weakness of the emissions and their possible time variability.

Reference:

A. Colaprete, G. Briggs, K. Ennico, D. Wooden, J. Heldmann, L.

Sollitt, E. Asphaug, D. Korycansky, P. Schultz, A. Christensen, K. Galal, and the LCROSS Team (2007): "An Overview of The Lunar Crater Observation and Sensing Satellite (LCROSS) Mission - An ESMD Mission

to Investigate Lunar Polar Hydrogen", LEAG Workshop on Enabling Exploration: The Lunar Outpost and Beyond, held October 1-5, 2007 in Houston, Texas. LPI Contribution No. 1371, p.3017

432.13 – **Broadband CCD Photometry of 2005 YU55 in Four Colors at McDonald Observatory**

Judit Gyorgyey Ries[1]

[1]*Univ. of Texas, Austin.*

9:00 AM - 2:00 PM

We present preliminary results of data collected on asteroid 2005 YU55 between November 13 and November 18 using the McDonald Observatory 0.76m telescope with the Prime Focus Corrector. This asteroid, which passed just within the Moon's orbit on November 8, 2011, was also observed by radio telescopes at Arecibo and Goldstone. We will complement the radar observations by providing colors as a function of the rotational phase. We have obtained CCD images spanning a total of 38.5 hours. The exposures through the B, V, R and I filters were spaced to sample the estimated 18-hour rotational period (based on Arecibo radar observations obtained in April 2010). The majority of the images were taken through the Bessel R filter in order to refine the rotation period. The phase coverage in colors is not quite even, but we can calculate colors for 5 or 6 different phases (depending on the actual rotational period). We have observed Landolt photometric standards to calibrate the target either directly or by calibrating the reference stars imaged with the targets.

This work was supported by the Planetary Group at UT Austin, Department of Astronomy.

432.14 – **Examining the Shape Distribution of Near-Earth Asteroids**

Abby A. Thane[1], E. S. Howell[2], M. C. Nolan[2], P. A. Taylor[2], C. Magri[3]

[1]*The University of Montana,* [2]*Arecibo Observatory, Puerto Rico,* [3]*University of Maine, Farmington.*

9:00 AM - 2:00 PM

We present the results of a population study investigating near-Earth asteroids and their shape distribution. Shapes can lead to clues of how asteroids form and evolve, providing constraints on solar system formation models. Data were collected from 1998 to 2010 using the S-band (2380 MHz) radar system at the Arecibo Observatory. Radar observations are one of the few ground-based techniques that can reveal shape and surface features, with resolution as fine as 7.5 m. Of the 309 asteroids observed, we used 144 in our study, only including data taken when the radar system was operating at over two thirds of its maximum sensitivity and only including objects that were both well-resolved and observed on multiple days (in order to determine the shape unambiguously). We separate these objects into four categories: spheroids, double-lobed objects, multiple-asteroid systems, and irregular asteroids. Current results indicate that although spheroids are slightly more numerous than other groups, none of the groups dominate the population. We also find there is no clear correlation between shape and H-magnitude, where H-magnitude is related to the diameter of an asteroid. Observations with H>23 (diameter<100m) are included although they are not well sampled. Further implications for the near-Earth asteroid population will be presented.

432.15 – **Physical Characterization of Near-Earth Object 3988 (1986 LA)**

Thien-Tin Truong[1], M. Hicks[2], C. Strojia[3], S. Teague[3], C. Gerhart[4], M. McCormack[5]

[1]*California State University - LA,* [2]*Jet Propulsion Laboratory/Caltech,* [3]*Victor Valley College,* [4]*Los Angeles Valley College,* [5]*Los Angeles City College.*

9:00 AM - 2:00 PM

The Near-Earth Object (NEO) 3988 (1986 LA) was discovered photographically by Glo Helin and colleagues with the 1.2-m Schmidt at Palomar (Helin et al. 1986: IAU Circ. 4228). With a perihelion distance q = 1.055 AU, 1986 LA is an Amor-type NEO. The spacecraft rendezvous potential of any small solar system body can be quantified, to first order, by the dV required to match the target's orbit. Using the method described by Shoemaker & Helin (1978; N7829022) and assuming a massless rendezvous target, a dV of 6.29 km/s is required to reach the orbit of Mars. Objects with dV < 6.29 km/s can therefor be considered low-dV targets: 1791 NEOs meet this criteria. 1986 LA has a dV of 5.84 km/s. With an absolute magnitude H = 17.7 (Lowell Astorb Database), the object is in the top 0.985 percentile in terms of expected size.

We obtained four nights of Bessel BVRI on 2011 June 14, 15, 16, and 18 at the JPL Table Mountain 0.6-m telescope. Our analysis was hampered by the high density of background stars, the low lunar elongation, and an intermittent tracking error. The rotationally averaged colors were found most consistent with an Ld-type spectral classification (Bus taxonomy), an association obtained through a comparison of our colors with the 1341 asteroid spectra in the SMASS II database (Bus & Binzel 2002). Despite the large error bars in our photometry we are confident that 1986 LA belongs to the S-family of asteroids (Tholen Taxonomy). Assuming a phase parameter G=0.15 and our V-R color, we measured an absolute magnitude H_V = 17.97 +/- 0.15 mag, intermediate between the H_V = 17.7 mag (Lowell) and H_V = 18.2 mag (JPL) database listings.

We observed for 21 additional nights. The pole positions are currently unresolved based on the further observations.

432.16 – **Evolutionary Models of Main Belt Comets**

Dina Prialnik[1], G. Sarid[2], K. Meech[2], A. Assis[1]

[1]*Tel Aviv Univ., Israel,* [2]*University of Hawaii.*

9:00 AM - 2:00 PM

The discovery of the new class of objects, known as Main Belt Comets (MBCs), raises several questions regarding their structure, composition and origin. Whether MBCs were formed in their present location or captured from more distant regions during the early bombardment era is still debated; either way, they have spent most of their lifetimes in the main belt, which has been considered too hot for ice to survive for any length of time. The low conductivity of porous cometary material suggests, however, that ice may be retained in the interior of MBCs, despite continual insolation. We show results of long-term evolutionary calculations for a model representing MBC 133P/Elst-Pizarro, considering different mixtures of ices and dust. The main conclusion is that crystalline water ice may survive at depths of 50-150m, but other volatiles will be completely lost. We then show results of a parameter study addressing the ice survival question by means of

long-term evolution calculations for a range of initial parameters: radii between 150m and 2.5km, two different density values, and two different orbits. We find that small bodies (< 600m in radius) may completely lose the ice over the age of the Solar System, especially if the density is low and they are relatively close to the Sun. By contrast, in larger bodies (a few km in size) that may have been captured or collisionally formed only 100 Myr ago, ice may be found at depths of only 10m. Such bodies could be easily activated by collisions to exhibit cometary activity. Finally, we investigate the effect of spin and latitude on the depth at which ice may be found and show that near the poles ice may survive quite close to the surface.

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433 – Binary and Variable Stars

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

433.01 – **Periodic Emission From The Gamma-ray Binary 1FGL J1018.6-5856**

Robin H.D. Corbet[1], Fermi-LAT collaboration, M. J. Coe[2], F. Di Mille[3], P. G. Edwards[4], M. D. Filipovic[5], J. L. Payne[5], J. Stevens[4], M. A. P. Torres[6]

[1]*UMBC/NASA GSFC,* [2]*University of Southampton, United Kingdom,* [3]*Australian Astronomical Observatory - Las Campanas Observatory, Chile,* [4]*CSIRO, Australia,* [5]*University of Western Sydney, Australia,* [6]*Harvard-Smithsonian Center for Astrophysics.*

9:00 AM - 2:00 PM

We present the discovery of a new gamma-ray binary system from a search for periodic modulation in the Fermi LAT light curves of all sources in the first Fermi-LAT catalog. 1FGL J1018.6-5856 was found to have a 16.6 day modulation in its gamma-ray flux that is accompanied by spectral variability. We identify counterparts in the X-ray, radio, and optical wavebands using data from the Swift XRT, ATCA, and telescopes at SAAO and LCO. The X-ray and radio counterparts are highly variable: the X-ray flux appears to be modulated on the orbital period with maximum X-ray flux coinciding with the phase of maximum gamma-ray flux. The optical counterpart has a spectral type of approximately O6V((f)) and shows little variability in a series of Swift UVOT observations. The overall properties of 1FGL J1018.6-5856 indicate that it is a member of the rare gamma-ray binary class of objects, and that it shares several properties with LS 5039. However, there are some differences from LS 5039, including the relative phasing of the gamma-ray flux and spectral modulation and the shape of the X-ray light curve. We conclude that 1FGL J1018.6-5856 is a new gamma-ray binary, and its discovery suggests that Fermi has begun to reveal the predicted population of such objects.

433.02 – **Studying the Environment of Symbiotic Stars with Spitzer IRS Spectroscopy**

Ryan P. Norris[1], F. C. Bruhweiler[2], B. McCollum[3], G. Wahlgren[4]

[1]*CUA,* [2]*CUA/NASA-GSFC,* [3]*IPAC/Caltech,* [4]*CUA/NASA.*

9:00 AM - 2:00 PM

We present high resolution (R~600) spectra of five symbiotic stars obtained with the Spitzer Space Telescope IRS instrument (9.9-37.2 microns). Of these stars, three (BI Cru, Hen2-104, and V1016 Cyg) are D-type, two (AS201 and V417 Cen) are D'-type, and one (AG Peg) is a S-type. The spectrum of AG Peg contains strong hydrogen recombination and emission lines, including lines of [Ne V] at 14.32 microns and 24.32 microns along with [O IV] 25.89 micron emission. All of the D-type stars contain silicate features and strong lines of ions of sulfur and neon. The spectra of the D'-type stars contain few strong emission lines, though the spectrum of AS201 does contain the [Ne II] 15.56 micron line. As part of a program to study the evolution and environments of symbiotic stars using Spitzer MIPS and IRS observations, we use line ratios and analysis of the silicates in the spectra to report environmental conditions in these systems.

433.03 – **Similarities and Differences in Spectral Behavior Between W Ser and UX Mon in the UV**

Matthew Bobrowsky[1], M. R. Sanad[2]

[1]*University of Maryland,* [2]*National Research Institute of Astronomy and Geophysics, Egypt.*

9:00 AM - 2:00 PM

We present ultraviolet spectra of two eclipsing interacting binary systems, W Ser and UX Mon. The data contain good coverage over the 14.16-day and 5.9-day orbital periods, respectively, using observations taken by the International Ultraviolet Explorer (IUE) during periods between 1978 - 1993 and 1981 - 1991 for the two systems respectively. Two profiles of both W Ser and UX Mon showing variations of line fluxes at two orbital phases are presented. We investigated the N V emission line at 1240 Å, C II emission line at 1336 Å, C IV emission line at 1550 Å, O III emission line at 1666 Å, and Si III emission line at 1892 Å (which are produced in an extended gaseous envelope around the mass-gaining component), by calculating the line fluxes of these spectral lines. Our results show that there are spectral variations of line fluxes at different orbital phases, correlated with the light curves found for both W Ser and UX Mon. We attribute these spectral variations to effects from the eclipse and to variations in the mass transfer rate.

M.B. acknowledges support from NASA, through grant number HST-AR-10304.04-A from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555.

433.04 – **Stellar Wind Ionization in High-Mass X-ray Binary Systems**

Rosina Iping[1], G. Sonneborn[1]

[1]*NASA's GSFC.*

9:00 AM - 2:00 PM

Archival far-ultraviolet spectra of three high-mass X-ray binary stars observed with the Far Ultraviolet Spectroscopic Explorer (FUSE) were analyzed to study the effects of the X-ray source on the stellar wind of the primary. The systems are SMC X-1, 4U1700-37 and the Be/X-ray binary 4U 1145-619. All three systems show phase-dependent changes in the stellar wind lines, indicating the pulsar ionizes the circumbinary material as it moves through the binary orbit, producing X-rays while accreting some of the ambient stellar wind from the massive primary star. Each system was observed at several phases of the binary period, which enabled us to determine spectral variability with phase. The spectra show significant variability in the P-Cyni wind profiles, especially O VI 1032-38.

433.05 – **VLT/X-shooter Spectroscopy Of The Candidate Black Hole X-ray Binary MAXI J1659-152**

Ramanpreet Kaur[1], L. Kaper[1], L. Ellerbroek[1], D. Russell[1], D. Altamirano[1], R. Wijnands[1], GRB/X-shooter team

[1]*University of Amsterdam, Netherlands.*

9:00 AM - 2:00 PM

MAXI J1659-152 which was discovered using Swift as a Gamma-ray-burst, was later on confirmed as a candidate Galactic black-hole X-ray binary. The source was intensively followed up by Swift and RXTE during its X-ray outburst and was revealed as a shortest period (2.4 hrs) black-hole X-ray binary. Following the X-ray outburst, we triggered the ESO-Very Large Telescope and obtained the optical and the near-infrared spectra of the source with the X-shooter spectrograph. The source was in low-hard state during our observations. The spectrum includes many broad (~ 2000 km/s) double peaked hydrogen and helium emission features. Two important results of our observations include the linear trend seen in the peak separation of the H lines with respect to the energy of their upper transitional levels and the considerable variability seen in the red-wing of the spectral line profiles between the two subsequent exposures. From our observations we estimated the distance to the source as ~ 4 +/- 1 kpc. We would like to present these results in the context of the accretion flows in the compact black hole X-ray binaries.

433.06 – **Optical Spectroscopy of ASAS 150946-2147.7**

Ishioka Ryoko[1]

[1]*NAOJ.*

9:00 AM - 2:00 PM

ASAS 150946-2147.7 is a transient object whose outburst was detected by ASAS in 2009 and reported as a DN-type CV. Its quiescent light curve shows an elliptical variability with an orbital period of 0.70242~d. Before the 2009 outburst, two outbursts were observed.

During the 2009 outburst, strong He II, CIII/NIII emission lines were observed superimposed on a late A or early F-type stellar spectrum, which shows RV variations out of phase. The A or F-type donor star and the orbital period of 0.70242~d are unusual for CVs, and the RV amplitudes in addition to X-ray detected by Swift indicate the possibility of a black hole or neutron binary.

We present high resolution spectroscopy of ASAS1509 taken a week after the 2009 outburst terminated. The spectrum is dominated by early-F type stellar spectrum, and shows no sign of other components. Vsin i measured from metal lines is 85 km/s and their RVs are well fitted by a sine curve with the semi-amplitude of 80 km/s, which is comparable with those of emission lines observed during the outburst.

This work is supported by JSPS Research Fellowships for Young **Scientists**.

433.07 – **SHRINKING DISK IN V926 SCO**

Sam Connolly[1], S. Vrtilek[1]

[1]*Harvard-Smithsonian Centre for Astrophysics.*

9:00 AM - 2:00 PM

We present phase-resolved spectroscopic observations of the low-mass X-ray binary V926sco, composed of a neutron star and a late-type secondary. The data were obtained using IMACS on the 6.5m Walter Baade telescope at Las Campanas Observatory. A full orbital period (4.65 hr) was obtained in June 2010, in addition to two partial periods in June 2011. Consistent with previous work, spectral lines in the spectrum of V926Sco include lines from H and He, as well as the Bowen blend of NIII and CIII fluorescence. Modulation tomograms using the strongest lines show that the inner disk velocities are significantly lower than those we have observed in black holes in quiescence (Neilsen et al. 2008; Calvelo et al 2009). The velocities are slightly lower than those observed in V926 Sco in 2003 (Casares et. al. 2006), suggesting that the inner radius of the disk has expanded since their observations: this is consistent with RXTE/ASM lightcurves of the object, which show that it has become less bright during that time. In H alpha we see emission concentrated on one side of the disk similar to that observed by Casares et. al. in HeII and interpreted by them as due to an extended disk bulge. We also find that the centre of the disk is offset from the neutron star's center of mass; we can correct this effect by adjusting the mass ratio to 0.1 which is well within the 0.05 -0.41 range suggested by Casares.

433.08 – **A Photometric and Spectroscopic Study of Eclipsing Binary AQ Serpentis**

Anthony Oliveri[1], C. Lacy[2]

[1]*University of Texas - Austin,* [2]*University of Arkansas.*

9:00 AM - 2:00 PM

I will be presenting my project in three parts: the observations of AQ Ser made by Dr. Claud Lacy and Dr. G. Torres, modeling the observations (using programs such as Phoebe, GLSPL, and JKTEBOP) and comparing the results to predictions from Yonsei-Yale models. My project confirms the prediction that the ages of the two stars should be within ten percent of each other. I thank NSF for providing the grant for my research.

433.09 – **X-ray Emission From Star-forming Galaxies**

Stefano Mineo[1], M. Gilfanov[2], R. Sunyaev[2]

[1]*Smithsonian Astrophysical Observatory,* [2]*Max-Planck-Institut für Astrophysik, Germany.*

9:00 AM - 2:00 PM

Based on a homogeneous set of X-ray, infrared and ultraviolet observations from Chandra, Spitzer, GALEX and 2MASS archives, we study populations of high-mass X-ray binaries (HMXBs) in a sample of 29 nearby star-forming galaxies and their relation with the star formation rate (SFR). In agreement with previous results, we find that HMXBs are a good tracer of the recent star formation activity in the host galaxy and their collective luminosity and number scale with the SFR, in particular, $L_X \sim 2.6 \times 10^{39}$ x SFR. However, the scaling relations still bear a rather large dispersion of rms ~ 0.4 dex, which we believe is of a physical origin. We present the catalog of 1055 X-ray sources detected within the D25 ellipse for galaxies of our sample and construct the average X-ray luminosity function (XLF) of HMXBs with substantially improved statistical accuracy and better control of systematic effects than achieved in previous studies. The XLF follows a power law with slope of 1.6 in the $\log L_X \sim 35$-40 luminosity range with a moderately significant evidence for a break or cut-off at $L_X \sim 10^{40}$ erg/s. As before, we did not find any features at the Eddington limit for a neutron star or a

stellar mass black hole. We discuss implications of our results for the theory of binary evolution. In particular we estimate the fraction of compact objects that once upon their lifetime experienced an X-ray active phase powered by accretion from a high mass companion and obtain a rather large number, fx ~ 0.2 x (0.1 Myr / tx) (tx is the life time of the X-ray active phase). This is ~ 4 orders of magnitude more frequent than in LMXBs. We also derive constrains on the mass distribution of the secondary star in HMXBs.

433.10 – **ATCA-CABB Observations of Neutron Star X-ray Binaries**

Daniel Calvelo[1], R. Fender[1], J. Broderick[1], M. Bell[1], T. Tzioumis[2], M. Nakajima[3]

[1]*University of Southampton, UK, United Kingdom,* [2]*ATNF, Australia,* [3]*Nihon University, Japan.*

9:00 AM - 2:00 PM

We present the results of radio observations of neutron star X-ray binaries (NSXRBs) Circinus X-1 and Scorpius X-1, using the Australian Telescope Compact Array Broadband Backend (ATCA-CABB). The first data set has allowed us to record the behaviour of Cir X-1 over a complete orbit, including a detailed view of one of the system's periodic 16.6 day flares. Analysis of images from the data shows variation in structure surrounding the system following the flare event, interpreted as re-energization of nearby material by invisible relativistic outflows. Large scale imaging of the region also reveals filament like structures in the jet-powered nebula surrounding Cir X-1, prompting comparison to the intricate structures observed in the micro-quasar SS 433 and its nebula W50. We follow this with the results of mm observations of both Cir X-1 and Sco X-1, yielding the first detections of NSXRBs at these wavelengths, as well as indications of re-energization occurring on sub-arc-second scales within Cir X-1. Comparison of the multiple Cir X-1 observations with archived data provides evidence of recent change in the system's jet orientation which could be explained by precession or outflow deviations. The authors acknowledge support from the United Kingdom Science and Technology Facilities Council, and the University of Southampton.

433.11 – **Surface Maps of LO Pegasi May-July 2011 Generated via BVRI Light Curve Inversion**

Robert O. Harmon[1], P. Johns Vidaurri[2], S. Krug[3]

[1]*Ohio Wesleyan Univ.,* [2]*Northern Arizona Univ.,* [3]*Univ. of Notre Dame.*

9:00 AM - 2:00 PM

The young solar analog LO Pegasi is a rapidly rotating (P ≈ 10.2 hr) K8 main sequence star known to exhibit large cool spots on its surface. We present surface maps based on BVRI photometry obtained at Perkins Observatory from May-July 2011 and inverted with an algorithm which makes no a priori assumptions regarding the number of spots or their shapes, and compare the results to images generated from 2006-2010. This work was supported by the NSF REU Program.

433.12 – **Long-Term Optical and Near-Infrared Spectroscopic Monitoring of ε Aurigae During the 2009-11 Eclipse**

John C. Barentine[1], W. F. Ketzeback[2], J. M. Dembicky[2], J. Huehnerhoff[2], R. McMillan[2], G. Saurage[2], A. Sheldon[2], J. Coughlin[3], N. Ule[3], S. Hawley[4], S. Schmidt[4], G. Wallerstein[4], R. Leadbeater[5], D. G. York[6]

[1]*University of Texas at Austin,* [2]*Apache Point Observatory,* [3]*New Mexico State University,* [4]*University of Washington,* [5]*Three Hills Observatory, United Kingdom,* [6]*University of Chicago.*

9:00 AM - 2:00 PM

We present the results of a program to spectroscopically monitor the long-period (P ~ 27 y) eclipsing binary ε Aurigae during the primary eclipse of 2009-11 with the ARC 3.5m telescope at Apache Point. Spectroscopic data from 3500-10000Å were obtained at a resolving power of R ~ 38000 and from 0.9-2.5μm at R ~ 3000 with a temporal cadence of approximately one week for the full duration of the eclipse. By noting the velocity centroids of certain weak metal lines (e.g., Na I D and K I 7699Å associated with the presumed optically-thick disk around the unseen secondary, we confirm a mid-eclipse epoch of HJD 2455384. The same lines indicate disk absorption with equivalent widths equal to or greater than the corresponding lines in the primary photosphere. The components of Hα and their evolution through the eclipse suggest the presence of weak ionized hydrogen, possibly distributed in a circumstellar ring or shell, and a separate, broad ionized component associated with the secondary disk in the form of a disk atmosphere or wind. Overall, our observations support the "consensus model" of ε Aur, consisting of a 2 M⊙, ~ F0 post-asymptotic giant branch primary and a dust-enshrouded, 6 M⊙ B8 dwarf. Variability of the profiles of certain lines such as Hα outside of eclipse encourages continued long-term synoptic monitoring of ε Aur between primary eclipses to better understand the circumstellar environment of the system.

433.13 – **Selection of RR Lyrae Stars**

Mohamad Abbas[1]

[1]*Astronomisches Rechen-Institut (ARI), Germany.*

9:00 AM - 2:00 PM

RR Lyrae stars are excellent tracers of old populations with the added advantage of being easily identifiable due to their variability.

Starting with known RR Lyrae stars from the Sloan Digital Sky Survey (SDSS), we explore methods of photometrically identifying such stars in other sky surveys as in the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS), which covers three times the area of the SDSS.

Our ultimate goal is to use RR Lyrae stars to study halo structure and substructure.

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434 – History

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

434.01 – **Franklin Edward Kameny (1925-2011, Astronomer)**

Jason Wright[1]

[1]*Penn State University.*

9:00 AM - 2:00 PM

Dr. Frank Kameny is best known today as one of the most important members of the gay rights movement in the United States, but he was also a PhD astronomer. In fact, it was his firing from his civil service position as astronomer for the US Army Map Service on the grounds of homosexuality that sparked his lifelong career of activism. Here, I explore some aspects of his short but interesting astronomical career and the role of the AAS in his life.

434.02 – **Where Did John Goodricke Make His observations? New Evidence**

Linda M. French[1]

[1]*Illinois Wesleyan Univ..*

9:00 AM - 2:00 PM

Much effort has gone into determining the location from which John Goodricke (1764-1786) made most of his observations. Sidney Melmore (1949) made the first determination, and he decided that the most likely location was a south-facing window of Treasurer's House, a large property facing onto York Minster, the largest Gothic cathedral in Northern Europe. Melmore made his determination by looking at the stars observed by Goodricke in his "Journal of the Going of My Clock," from which it is possible to infer the direction in which Goodricke was looking. There are problems with Melmore's identification, however: the wing of Treasurer's House he identified was, at that time, occupied by several spinster daughters of a wealthy landowner. The presence of these ladies makes it unlikely that a teenaged boy would have been allowed in to make astronomical observations at night. An alternative solution is presented.

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435 – AGN, QSOs & Friends

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

434.04 – **Multiwavelength Campaign on Mrk 509 IX: Limits on the Distance of the Absorber from HST COS and STIS Spectroscopy**

Doug Edmonds[1], N. Arav[1], B. Borguet[1], G. A. Kriss[2]

[1]*Virginia Tech,* [2]*Space Telescope Science Institute.*
9:00 AM - 2:00 PM

Active Galactic Nuclei often show strong photoionized outflows. A major uncertainty in models for these outflows is the distance to the gas from the central black hole. In this paper we use HST/COS data from a massive multiwavelength monitoring campaign on the Seyfert I galaxy Mrk 509 in combination with archival HST/STIS data to constrain the location of the outflow. We contrast the expected response of the photoionized gas to changes in ionizing flux with the changes measured in the data using the following steps: 1) Comparing the column densities of each kinematic component measured in the 2001 STIS data to those measured in the 2009 COS data; 2) Using time-dependent photionization calculations along with Monte Carlo simulations of lightcurves to determine the upper limit to the hydrogen number density that will be consistent with the small observed changes in the ionic column densities; 3) Transforming the upper limit on the hydrogen number density to a lower limit on the distance to the absorber from the central source via the prior determination of the ionization parameter. The very small variations in ionic column densities (mostly consistent with no change) between the 2001 and 2009 epochs allow us to put a lower limit on distances between 100-200 pc for all the major UV absorption components. These results are in good agreement with the independent distance estimates derived for the simultaneous X-ray absorber data.

435.01 – **Application of Data Visualization Techniques to Studying the Narrow Line Region of Seyfert Galaxies.**

Charles H. Nelson[1], T. Urness[1], J. Mirocha[2], K. Kreimeyer[3], W. Kockler[1], J. Albrechtson[1]

[1]*Drake Univ.,* [2]*Univ. of Colorado,* [3]*Univ. of Maryland.*
9:00 AM - 2:00 PM

Ionized gas in the narrow line regions of Seyfert galaxies is often accelerated by processes related to the active nucleus to velocities of several thousand km/s. Several mechanisms to drive these outflows have been proposed including the interaction of radio jets, nuclear winds or radiation pressure. Recent studies involving STIS longslit and slitless spectra have reached differing conclusions as to the nature of these outflows. Interpretation of these data in terms of dynamic models is complicated by the number of parameters involved. We have developed an interactive data visualization tool to investigate these issues and have begun analysis of the two prototype Seyfert galaxies NGC 4151 and NGC 1068. This is very much work in progress and importantly involves undergraduate research participation.

435.02 – **The First Direct Measure of BAL Quasar Orientations**

Michael A. DiPompeo[1], M. S. Brotherton[1], C. De Breuck[2], S. Laurent-Muehleisen[3], A. D. Myers[1]

[1]*University of Wyoming,* [2]*European Southern Observatory, Germany,* [3]*Illinois Institute of Technology.*
9:00 AM - 2:00 PM

Broad Absorption Line (BAL) quasars make up a significant fraction of the population of optically selected quasars, yet their nature is still debated. A common explanation for the presence of BALs in only a subset of all quasar spectra is orientation; it is argued that these sources have high velocity outflows in a mostly equatorial wind, and we only observe them when they are viewed more edge-on (farther from the accretion disk symmetry axis) than normal quasars. However, no direct measure of the orientation of these sources has been done, and several of their observational properties are difficult to explain with only geometrical arguments. This has led to a dichotomy in this area of study, where either BAL sources are seen from a particular viewing angle, or they are a particular evolutionary stage in the lifetime of all quasars. We have conducted a survey with the EVLA at two frequencies of BAL sources and a well-matched sample of unabsorbed quasars found in both SDSS and the FIRST survey. The goal was to measure the radio spectral index (α) of a large sample, as α is a statistical indicator of source orientation. We find that BAL quasars do show a significantly different spectral index distribution compared to normal quasars, though both have a large range, indicating that BAL sources cover a range of orientations but more often have higher viewing angles than non-BAL sources. We then performed Monte-Carlo simulations of these distributions to quantify the range of viewing angles to these objects.

I gratefully acknowledge the Wyoming NASA Space Grant Consortium for funding a portion of this work and travel.

435.03 – **Evolution of the Black Hole Mass - Galaxy Bulge Relationship for Quasars in the Sloan Digital Sky Survey Data Release 7**

Sarah Salviander[1], G. A. Shields[1]

[1]*University of Texas at Austin.*
9:00 AM - 2:00 PM

We investigate evolution in the relationship between black hole mass and host galaxy velocity dispersion for a sample of QSOs from the Sloan Digital Sky Survey Data Release 7. Due to the lack of resolution and the high luminosity of our QSOs, we use surrogates for the black hole and galaxy properties. We use the broad Hβ emission line and the QSO continuum to estimate the black hole mass, and the narrow [O III] emission line as a proxy for the host galaxy velocity dispersion. This allows us to probe the relationship to redshift $z = 0.8$. For higher redshifts, we use Mg II and [O II] in place of Hβ and [O III], respectively, which increases our redshift range to $z \sim 1.2$. The large number of QSOs in our sample allows us to investigate the black hole mass - host galaxy velocity dispersion relationship for separate black hole mass bins. We find no significant evolution in the relationship for all but the highest black hole mass bin, which includes QSOs with log black hole mass > 9.0. The highest-mass bin shows about a factor of three evolution in the redshift range $0.5 < z < 1.2$, in the sense that black holes become increasingly more massive compared with the mass predicted by the velocity dispersion and the local black hole mass - host galaxy velocity dispersion relationship.

435.05 – **3c 449: Is It A Merging Radio Galaxy?**

Dharam V. Lal[1], R. Kraft[1], S. Randall[1], M. Hardcastle[2], W. Forman[1], P. Nulsen[1], C. Jones[1], J. Croston[3]

[1]*Harvard-Smithsonian Center for Astrophysics,* [2]*University of Hertfordshire, United Kingdom,* [3]*University of Southampton, United Kingdom.*
9:00 AM - 2:00 PM

We present our understanding from a deep Chandra observations of 3C449 complemented with the archival Very Large Array radio observations, a canonical FR I radio galaxy, to study a large scale gas emission in a nearby ($z = 0.017$) 1.5 keV group. We find multiple surface brightness discontinuities in the gas, probably shocks, which are indicative of the supersonic inflation of the radio lobes. We also find X-ray cavities in the group gas coincident with the radio lobes. Surprisingly, there is no X-ray synchrotron emission associated with the inner jet at flux levels well below that observed in other nearby Fanaroff-Riley Class I sources.

435.06 – **Physical Conditions And Kinematics Of The Molecular Gas In Feedback-dominated Radio Galaxies**

Pierre Guillard[1], P. Ogle[2], B. Emonts[3], P. Appleton[4], R. Morganti[5]

[1]*Caltech,* [2]*IPAC, Caltech,* [3]*Australia Telescope National Facility, CSIRO, Australia,* [4]*Nasa Herschel Science Center, IPAC, Caltech,* [5]*Netherlands Foundation for Research in Astronomy, Netherlands.*
9:00 AM - 2:00 PM

Active Galac Nuclei (AGN) feedback is widely introduced in numerical simulations of galaxy evolution to clear the circum-nuclear gas, thus regulating star formation and preventing the formation of too many massive galaxies in the early universe. However, the impact of AGN feedback on the molecular gas is largely unexplored. Our mid and near-IR spectroscopy of radio-galaxies with fast winds of ionized gas shows that the dissipation of AGN feedback kinetic energy involves the formation and heating of large amounts of molecular gas, on galactic scales, without necessarily implying an outflow of molecular material. This poster presents observations and modeling to characterize the physical state and morpho-kinematics of the molecular gas in a sample of powerful radio galaxies, with the aim of understanding the entrainment of material in winds and ultimately how feedback processes regulate star formation and galaxy growth.

435.07 – **Investigating The Core Morphology--seyfert Class Relationship Using Archival Hubble Space Telescope Images Of Local Seyfert Galaxies**

Rogier A. Windhorst[1], M. J. Rutkowski[1], P. Hegel[1], H. Kim[1], K. Tamura[1], M. R. Corbin[1]

[1]*Arizona State Univ..*
9:00 AM - 2:00 PM

The Unified Model of Active Galactic Nuclei (AGN) has provided a remarkably successful explanation for the diversity of AGN in both the local and the distant Universe. Recently, the analysis of multi-wavelength spectral and imaging data has found evidence that the Unification Model may be only a partial theory of AGN, requiring a modification to accommodate the full observed diversity of AGN in the local Universe.

For example, high spatial resolution ground- and space-based observations of local Seyfert galaxies has determined that the Seyfert class of the AGN and the central (r<=1 kpc) host galaxy morphology are not randomly associated.

Specifically, of galaxies which host AGN, those with dustier ``later-type''

cores are found to be more often associated with Type 2 Seyfert galaxies. In contrast, Type 1 Seyfert host galaxies are more often identified with ``early-type'' galaxy cores. At present, this relationship has only been established by visual inspection and classification of the core morphologies of local Seyfert host galaxies.

In this project, we first re-examine this trend visually. Next, we attempt to re-establish the core morphology-Seyfert class relationship using an automated, parametric approach which combines both existing classification schemes and a novel method which uses the SExtractor software for object detection. We discuss to what extent one can establish or

confirm this relationship using this new approach.

This research was supported by NASA ADAP grant NNX10AD77G.

435.08 – **The Origin of the Hot Dust Poor Quasars**

Heng Hao[1], M. Elvis[2], L. Danese[1], A. Celotti[1]

[1]*SISSA, Italy,* [2]*Smithsonian Center for Astrophysics.*

9:00 AM - 2:00 PM

In the XMM-COSMOS type 1 AGN sample, 10% of the quasar are identified to be hot dust poor (HDP, Hao et al. 2010). Similar fraction of the HDP are also found in other samples (Hao et al. 2011, Mor et al. 2011). These quasars have weak or non-existent near-IR bumps, suggesting a lack of the hot dust characteristic of AGNs. The 1-3micron emission is a factor 2-4 smaller than the typical E94 AGN SED. The implied 'torus' covering factor is 2%-29%, well below the 75% required by unified models.

The origin of the HDP quasars is unknown. We test on several possibilities as the first step. We compared the the HDP quasar distribution with the Volonteri & Madau (2008) estimation of off-nuclear AGN distribution and found that these two distributions match well with each other. Alternatively, we compared the distribution of the dust covering factor distribution of the XMM-COSMOS sample with the Lawrence & Elvis (2011) tilted disk model. The two distributions generally agrees with each other. The optical and X-ray spectrum and the far infrared SEDs still needs to be checked to get a clearer picture of the origin of HDP quasars.

435.09 – **Dual Frequency VLBI Monitoring of a Large Sample of Compact Extragalactic Sources at 8 and 32 GHz**

Christopher S. Jacobs[1], W. A. Majid[1], A. Romero-Wolf[1], L. Snedeker[1], C. Garcia-Miro[2], I. Sotuela[2], S. Horiuchi[3]

[1]*JPL,* [2]*INSA, Spain,* [3]*CSIRO, Australia.*

9:00 AM - 2:00 PM

We are carrying out regular monitoring of 400+ compact extragalactic sources using large DSN (Deep Space Network) antennas over intercontinental baselines at 8, and 32 GHz simultaneously. This program provides precision astrometric measurements of AGN compact cores, used to maintain the JPL extragalactic reference frame. In addition to astrometric observables, this program has the potential to provide regular flux density measurements at each of these observing frequencies with precision at the level of 10-20%.

Such monitoring of compact radio emission serves as a direct measure of AGN core activity, probing intrinsic jet parameters and providing the opportunity for discriminating between different models of the high-energy emission in these objects by cross-correlating the radio and gamma-ray flux densities. Simultaneous multi-frequency observations will provide high precision spectral information of AGN compact emission regions at the parsec-scale unaffected by the errors often introduced when combining multi-frequency data obtained at different epochs. The spectral index can be used to compare the relativistic electron energy distribution with the photon spectral index seen in gamma-rays. For instance, if Compton up-scattering by the radio synchrotron electron population is the basic process producing the gamma-rays, the spectra in both spectral regions should be directly related.

By providing measurements on both East-West and North-South baselines with large antennas and Gbit/s recording capability, our program can probe sources at the 30 mJy flux limit (10-sigma), potentially increasing the sample to a fainter population of sources. In these regards, our program complements well existing northern and southern hemisphere VLBI monitoring programs, by providing flux measurements at 32 GHz, covering a fainter population sample, and by filling the gap for sources in the [-20:-40] degree declination range. Further, our program also provides additional flexibility for target of opportunity observations.

435.10 – **Recalibrating Single-epoch Black Hole Mass Estimates**

Jong-Hak Woo[1], D. Park[1], T. Treu[2], A. J. Barth[3], M. C. Bentz[4], V. N. Bennert[5], G. Canalizo[6], A. V. Filippenko[7], E. Gates[8], J. E. Greene[9], M. A. Malkan[10], J. Walsh[11]

[1]*Seoul National University, Korea, Republic of,* [2]*UC Santa Barbara,* [3]*UC Irvine,* [4]*Georgia State University,* [5]*California Polytechnic State University,* [6]*UC Riverside,* [7]*UC Berkeley,* [8]*Lick Observatory,* [9]*Princeton University,* [10]*UCLA,* [11]*UT Austin.*

9:00 AM - 2:00 PM

Using the high-quality multi-epoch spectra of 9 Seyfert 1 galaxies from the Lick AGN Monitoring Project, we investigate uncertainties of black hole mass estimates, and calibrate mass estimators based on the reverberation results. First, we introduce new methods to improve the root-mean-square (rms) spectra by adopting spectral decomposition and S/N weighting of each singe-epoch (SE) spectra, leading to substantially improved quality of the rms spectra. Second, based on the variability of the Hβ line width and AGN continuum luminosity, we estimate the uncertainty in SE mass estimates due to the combined variability as 12%. This is much lower than the total uncertainty 0.46 dex (factor of 3), which is dominated by uncertainties in virial coefficient. Third, we find that the Hβ line is broader in SE spectra than in the rms spectra by 25%. To correct for this systematic difference, we recalibrate the SE black hole mass estimators by introducing a line-width dependent virial factor.

This work has been supported by the Basic Science Research Program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology (2010-0021558).

435.11 – **The Ideal AGN Atlas of AGN Theoretical Images and Spectra**

Brandon Marshall[1], M. Bautista[1]

[1]*Western Michigan University.*

9:00 AM - 2:00 PM

We construct 3D numerical models of AGN using the SHAPE modeling code. The models include the basic characteristics, physical scales, and dynamic and spectral properties expected according to the AGN standard model. Then, we produce an atlas of predicted images, spectra, and photometry according to the SDSS photometric fluxes for a wide range of AGN geometric orientations, black hole masses and accretion rates. We expect that the present atlas will be useful in statistical interpretations of observations of large samples of AGN.

435.12 – **Determination Of The Kinetic Luminosity Of The High Ionization UV Outflow In SDSS J1512+1119 Using High S/N VLT/X-Shooter Spectrum**

Benoit Borguet[1], N. Arav[1], D. Edmonds[1], C. Chamberlain[1]

[1]*Virginia Tech.*

9:00 AM - 2:00 PM

We present the analysis of the physical conditions and location of the UV outflow in the BAL quasar SDSS J1512+1119 (z=2.1099) based on the high S/N, medium resolution VLT/X-Shooter spectrum obtained in late April 2011. The outflow is detected in five distinct kinematic components spanning a velocity range of vout = -1000 to -3000 km/s. Component T2 (vout =-2200 km/s) shows, within the X-Shooter spectral range, absorption troughs associated with a multitude of ions such as the high ionization lines CIV, NV, OVI, low ionization species like CII, MgII, SiII, SiIII, SiIV, SIV and low abundance elements like PV allowing us to derive an accurate photoionization solution for the gas. The detection of troughs from excited states of CII, CIII, SiII and SIV allows us to estimate the gas density and derive the distance of the ionized gas to the central source, hence the mass flow rate and kinetic luminosity of this high ionization outflow.

435.13 – **Data Mining of the Sloan Digital Sky Survey: Finding Follow-Up Targets for the Hubble Space Telescope**

Sarah True[1], N. Arav[1], Quasar Outflow Group at Virginia Tech

[1]*Virginia Polytechnic Institute and State University.*

9:00 AM - 2:00 PM

The aim of the project is to use the Sloan Digital Sky Survey (SDSS) to data mine the spectra of quasars and identify redshifted absorption troughs as outows. SDSS collects data on a variety of objects in the universe, but our interest is in Active Galactic Nuclei (AGN) and outows of quasars. The database search paves the way for follow-up analysis including determining the mass ux, kinetic luminosity, column density, and other physical parameters of the outow. Of the thousands of SDSS objects, the ones deemed most interesting are analyzed using computer software that identi es doublets in the spectra such as CIV, SiI, and NV. Each line of spectra is examined for excited ions that are used in the calculation of the hydrogen number density. This is the rst step in a long process to learn more about the outows of quasars and AGN. Currently, we have dozens of objects ready to explore further with higher resolution telescopes such as the William Herschel Telescope, the Very Large Telescope at the European Southern Observatory in Chile and also the Hubble Space Telescope.

435.14 – **Physical Properties Of The NLR In Low-mass Active Galaxies**

Randi R. Ludwig[1], J. E. Greene[2], A. J. Barth[3], L. C. Ho[4]

[1]*University of Texas,* [2]*Princeton University,* [3]*University of California, Irvine,* [4]*Observatories of the Carnegie Institution for Science.*

9:00 AM - 2:00 PM

We present high-resolution spectroscopic observations of 27 active galactic nuclei (AGN) with black hole masses M_BH < 2 × 10^6 M⊙. We investigate their narrow emission line properties and compare them with those of AGN with higher mass black holes. While we are unable to determine absolute metallicities, these low-luminosity objects plausibly represent AGN with sub-solar metallicities, based on their [N II]/Hα ratios and their consistency with the Kewley et al. (2008) mass-metallicity relation. We find that these low-mass AGN have UV continuum slopes similar to those of more massive AGN based on their He II/Hβ ratio, similar blueshifts and broadening in their narrow lines with respect to ionization potential, and we see evidence of an intermediate line region whose intensity correlates with L/L_Edd in these objects. In contrast to higher-mass AGN, we find that the low-mass AGN have selectively high narrow line EWs when [O III] shows no blue wing, which could be explained by a high covering factor of lower ionization gas in the narrow-line region of objects with symmetric

emission lines.

435.15 – **Spitzer and Herschel-based SEDs of 24 µM-bright z~0.3-3.0 Starbursts and Obscured Quasars**

Anna Sajina[1], L. Yan[2], D. Fadda[3], K. Dasyra[4], M. Huynh[5]

[1]Tufts University, [2]IPAC, Caltech, [3]NASA Herschel Science Center, [4]Observatoire de Paris, France, [5]University of Western Australia, Australia.

9:00 AM - 2:00 PM

We make use of the recently released HerMES SPIRE maps of the First Look Survey field to characterize the full infrared SED and measure the total infrared luminosities for a sample of 191 S24>0.9mJy sources in the Spitzer FLS field for which we also have Spitzer mid-IR spectroscopy. Our sources cover the redshift range z~0.3--2.8 and the luminosity range $LIR \sim 10^{11}$-10^{13}Lsun.

The full IR SED analysis shows that the fraction of AGN-dominated systems is much smaller than inferred from the mid-IR alone, only 19%,the fraction of SB-AGN composites $L_{IR}(AGN)/L_{IR}$~30%-50%) is 31% and the fraction of starburst dominated galaxies ($L_{IR}(AGN)/L_{IR}$<30%) has increased to 49%.We construct a set of IR SEDs template library for mid-IR bright ULIRGs at high redshifts.

The templates will be released to public and useful for interpreting the all-sky mid-IR data from WISE.

435.16 – **Comparing Optical And X-ray Spectra Of Swift/BAT-selected Agn**

Stuart Flury[1], M. L. Trippe[2]

[1]Dickinson College, [2]University of Maryland - College Park.

9:00 AM - 2:00 PM

The Swift Burst Alert telescope 58-month catalog has produced a catalog of AGN selected without bias by Compton-thin obscuration. Here, we utilize publicly-available SDSS/6df and XMM-Newton archival data to compare the optical and X-ray characteristics of the BAT AGN, and note those objects with unusual spectral properties.

435.17 – **Steps Toward Unveiling the True Population of AGN: Photometric Selection of Broad-Line AGN**

Evan Schneider[1], C. Impey[1]

[1]University of Arizona.

9:00 AM - 2:00 PM

We present an AGN selection technique that enables identification of broad-line AGN using only photometric data. An extension of infrared selection techniques, our method involves fitting a given spectral energy distribution with a model consisting of three physically motivated components: infrared power law emission, optical accretion disk emission, and host galaxy emission. Each component can be varied in intensity, and a reduced chi-square minimization routine is used to determine the optimum parameters for each object. Using this model, both broad- and narrow-line AGN are seen to fall within discrete ranges of parameter space that have plausible bounds, allowing physical trends with luminosity and redshift to be determined. Based on a fiducial sample of AGN from the catalog of Trump et al. (2009), we find the region occupied by broad-line AGN to be distinct from that of quiescent or star-bursting galaxies. Because this technique relies only on photometry, it will allow us to find AGN at fainter magnitudes than are accessible in spectroscopic surveys, and thus probe a population of less luminous and/or higher redshift objects. With the vast availability of photometric data in large surveys, this technique should have broad applicability and result in large samples that will complement X-ray AGN catalogs.

435.18 – **Precious Metals In SDSS QSOs: The Hunt For Intergalactic CIV In DR7**

Kathy Cooksey[1], M. Kao[2], R. Simcoe[3], J. O'Meara[4], J. Prochaska[5], E. Seyffert[3]

[1]MIT Kavli Institute for Astrophysics & Space Research, [2]Caltech, [3]MIT, [4]St. Michael's College, [5]UC Santa Cruz.

9:00 AM - 2:00 PM

The CIV doublet has proven to be an important tracer of the IGM and its evolution from z = 6 to 0. These transitions have been well-studied at high redshifts because: they are strong transitions of common metals; they are observable outside the Ly-alpha forest, where they become easier to identify; they redshift into optical passbands for $1.5 < z < 4.5$; and they are resonant doublets, which give them distinctive characteristics and enable the survey to be largely automated. However, the $1.5 < z < 4.5$ results can be vastly improved by surveying the thousands of SDSS DR7 QSOs. Having done this, we now present early results on the over 15,000 CIV systems that we identified. We are constructing a uniform $0 < z < 6$ dataset by combining the SDSS survey with the $z < 1$ HST results (Cooksey et al. 2010) and the new $z > 5$ FIRE results (Simcoe et al. 2011). Thus, we can compare apples-to-apples: the absorber line density over time and the CIV mass density evolution. This is the first in a series on our surveys for various metal-line absorption systems in SDSS DR7 QSOs.

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436 – Supernovae & Related Topics

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

436.01 – **Off-center Collisions of two White Dwarfs: A Type Ia Supernova Progenitor Scenario.**

Themis Athanassiadou[1], W. Hawley[1], F. Timmes[1]

[1]Arizona State University.

9:00 AM - 2:00 PM

We present 3D simulations of off-center collisions between two white dwarfs (WD) to explore the possibility of such events being part of the overall Type Ia Supernovae (SNIa) population. In particular, we investigate collisions of carbon-oxygen white dwarfs of various mass combinations and impact parameters using a combination of Lagrangian and Eulerian computational techniques. Pre-collision, the white dwarfs are evolved using SNSPH, an implementation of Smooth Particle Hydrodynamics (SPH), which ensures that the angular momentum of the system is conserved. At the point of contact between the WDs, the results are mapped onto FLASH, an Eulerian adaptive-grid code which is adept at capturing shock structures. Preliminary results indicate 0.0 - 0.5 solar masses of 56Ni and 0.1 - 0.3 solar masses of unburned carbon and oxygen, making such collisions a candidate for producing sub-luminous supernovae, such as SN 1991bg, SN 1992K, and SN 2005bl.

436.02 – **The Progenitor Masses Of Type IIP Supernovae From Late-time Spectral Modeling**

Anders Jerkstrand[1]

[1]Stockholm University, Sweden.

9:00 AM - 2:00 PM

Type IIP supernovae (SNe) arise in the core-collapse of massive stars that have retained most of their hydrogen envelopes throughout their evolution. Progenitor analysis and hydrodynamical modeling have given strongly conflicting results for which type of stars are responsible for these explosions. We apply nebular-phase spectral modeling to diagnose the nucleosynthesis in these SNe, which is related to their progenitor ZAMS masses. I discuss results for the nearby SN 2004et as well as other Type IIP SNe.

436.03 – **Host Galaxy Environments of Supernovae**

Patrick Kelly[1]

[1]Stanford University.

9:00 AM - 2:00 PM

Using Sloan Digital Sky Survey (SDSS) imaging and spectroscopy, I have measured the colors near the explosion sites of core-collapse SN, as well as the chemical abundances, and specific star formation rates of core-collapse host galaxies. These show the environmental dependence of pre-explosion mass loss for stripped-envelope SN progenitors as well as the presence of high velocity ejecta (i.e., broad-lined Type Ic SN). I present ongoing analysis of follow-up spectroscopic measurements of oxygen abundance at the explosion sites of core-collapse SN with the Mayall telescope. I then turn to a comparison between the host galaxy M-Z relation for core-collapse SN discovered through galaxy-impartial search programs and that for long duration gamma-ray bursts (LGRBs), consistently estimated from line strengths from the SDSS and the literature. This juxtaposition may offer insight into the origin of the metal-poor M-Z relation observed for LGRB host galaxies.

436.04 – **Sn 2010kd -- A Super-luminous, Pair-instability Supernova?**

Jozsef Vinko[1], W. Zheng[2], S. B. Pandey[3], R. Quimby[4], A. Romadan[2], R. Roy[3], K. Takats[1], E. Chatzopoulos[5], J. C. Wheeler[5], N. Whallon[2], F. Yuan[6], C. Akerlof[2], D. Pooley[7]

[1]University of Szeged, Hungary, [2]University of Michigan, [3]ARIES, India, [4]IPMU University of Tokyo, Japan, [5]University of Texas, [6]RSAA Australian National University, Australia, [7]Sam Houston State University.

9:00 AM - 2:00 PM

SN 2010kd was discovered by the ROTSE Supernova Verification Project in a faint, metal-poor dwarf galaxy at z=0.101. The first optical spectra, obtained with the Hobby-Eberly Telescope, showed weak, broad SN-like features superimposed on a blue continuum. Modeling the early spectra with SYNOW identified no H or He, but CII, OI and OII, revealing that SN 2010kd is a peculiar Type Ic SN. A strong UV deficit in the early spectra can be fit with Co III. The spectrum and light curve exhibited unusually slow evolution. Peak brightness in the optical, corresponding to -21.1 mag absolute, occurred about 40 days after discovery After peak brightness, the spectrum slowly developed strong features of OI, OII, MgII, and FeII, and became very similar to the

spectrum of SN 2007bi, a candidate Pair-Instability SN (PISN) event. The latest spectrum obtained with Keck at +192 days after peak still showed strong, broad photospheric features, consistent with the observed slow evolution of SN 2007bi. Comparison of the observed rise time to maximum with simple radioactive decay photon diffusion models gives an estimated ejecta mass of 23 M_{sun}, and a nickel mass of 10 M_{sun}. These parameters are more tightly constrained than in the case of SN 2007bi, because our light curve covers the pre-maximum phases much better. The derived Ni-mass favors a PISN event, but the ejecta mass seems to be too low compared to the prediction of such models (~ 100 M_{sun}), challenging the proposition that PISN is the explosion mechanism of SN 2010kd.

436.05 – **White Dwarf Collisions: Grid versus Particle Codes**

Wendy Hawley[1], T. Athanassiadou[1], F. Timmes[1], C. Raskin[1], M. Richardson[1]

[1]*Arizona State University.*

9:00 AM - 2:00 PM

We present zero impact parameter 3D collisions of white dwarfs using the Eulerian adaptive grid code FLASH for 0.64-0.64 M⊙ (henceforth 2x0.64) and 0.81-0.81 M⊙ (henceforth 2x0.81) pairings spanning a range of maximum spatial resolution from 5.2E7 to 1.2E7 cm. We find that the 2x0.64 head-on collision produces 0.32 M⊙ of Ni-56, and the 2x0.81 head-on collision produces 0.39 M⊙ of Ni-56. Both simulations also yield ~0.2 M⊙ of unburned C-12+O-16, and their nucleosynthetic yields are consistent with those in subluminous supernova Type Ia. A parallel study carried out using a Lagrangian particle code SNSPH for the same configurations show larger Ni-56 production, 0.48 M⊙ of Ni-56 for the 2x0.64 collision and 0.84 M⊙ of Ni-56 for the 2x0.81 collision, and we apply a new SNSPH-to-FLASH mapping tool to compare the results. We find the Ni-56 yields from these models are similar to our initial simulations - 0.26 M⊙ of Ni-56 for the 2x0.64 collision and 0.36 M⊙ of Ni-56 for the 2x0.81 collision - indicating that the differences in 56Ni yields are not due to differences in pre-collision conditions. Instead, we attribute the differences in 56Ni production to differences in the pre-detonation pressure and temperature profiles. We explore the possible causes for these profile differences, and conclude that a higher pre-detonation peak temperature in SNSPH is the most likely cause.

436.06 – **Modelling Spectra and Lightcurves from Supernovae**

Lucille Frey[1], W. Even[2], D. Whalen[3], C. Fryer[2], A. Hungerford[2], C. Fontes[2]

[1]*LANL, University of New Mexico,* [2]*LANL,* [3]*Carnegie Mellon University.*

9:00 AM - 2:00 PM

Explosive transient astronomy is entering an era where supernovae (SNe) and gamma-ray bursts will be observed in real time with surveys like the LSST and Pan-STARRS, probing the universe back to very early times. The discovery of Pop III SNe could reveal many details about the formation and evolution of the first stars. Observations of shock breakout in SNe will provide new information about the engines powering these explosions. Shock breakout occurs when the shock wave from core collapse reaches an optically thin region and radiation can stream out. This first burst of radiation interacts with the star's immediate surroundings, showing the effects of the surrounding environment on emission and evolution. This profusion of data will contain brief snapshots from a wide range of progenitor systems which simulations can help interpret and explain. We present a new pipeline for creating model supernova spectra and lightcurves using radiation-hydrodynamic simulations and a new Spectrum code. Spectrum maps 1-D or 2-D data onto a two dimensional grid and assumes rotational symmetry, using monochromatic opacities to calculate emission and absorption as a function of radius and angle. We use these spectra to create lightcurves in any band from infrared to x-ray. This pipeline is being used to study the effects of stellar environment on core-collapse and Type Ia SNe, as well as several types of Pop III SNe.

436.07 – **Early Radio and X-ray Observations of the Youngest Nearby Type Ia Supernova PTF11kly (SN 2011fe)**

Assaf Horesh[1]

[1]*Caltech.*

9:00 AM - 2:00 PM

On August 24 (UT) the Palomar Transient Factory (PTF) discovered PTF11kly (SN 2011fe), the youngest and most nearby type Ia supernova (SN Ia) in decades. We followed this event up in the radio (centimeter and millimeter bands) and X-ray bands, starting about a day after the estimated explosion time. We present our analysis of the radio and X-ray observations, yielding the tightest constraints yet placed on the pre-explosion mass-loss rate from the progenitor system of this supernova. We find a robust limit of dM/dt ≤ 10^-8 (w/100 km/s) M⊙/yr from sensitive X-ray non-detections, as well as a similar limit from radio data, which depends, however, on assumptions about microphysical parameters. We discuss our results in the context of single-degenerate models for SNe Ia and find that our observations modestly disfavor symbiotic progenitor models involving a red giant donor, but cannot constrain systems accreting from main-sequence or sub-giant stars, including the popular supersoft channel. In view of the proximity of PTF11kly and the sensitivity of our prompt observations we would have to wait for a long time (decade or longer) in order to more meaningfully probe the circumstellar matter of Ia supernovae.

436.08 – **The Critical Neutrino Luminosity in Rotating Core-Collapse Supernovae**

Sean M. Couch[1]

[1]*University of Chicago.*

9:00 AM - 2:00 PM

Numerical simulations of core-collapse supernovae suggest that the critical neutrino luminosity necessary to cause explosions is dependent on dimensionality. The lower threshold for explosion in 2D versus 1D has been well-documented, but recently Nordhaus et al. (2010) have found that going to 3D simulations further reduces the critical neutrino luminosity by around 20 \% as compared with 2D simulations. This result may reflect the fundamental difference in the development of turbulence between 2D and 3D simulations and may indicate that 3D simulations are critically necessary to study core-collapse supernovae. The conclusion that the critical neutrino luminosity is reduced in 3D simulations is not yet well-established, however. Hanke et al. (2011) conducted a study similar to that of Nordhaus et al. and find that, while the critical luminosity in 2D is lower than in 1D, going to 3D does not result in a significantly lowered critical neutrino luminosity for explosion. This leaves open the question of the importance of 3D simulations and what physical mechanisms reduce the critical neutrino luminosity in simulations of core-collapse supernovae. I will discuss our recent effort to examine the dependence of the critical neutrino luminosity on dimensionality. Our approach is similar to those of Nordhaus et al. and Hanke et al., implemented in the FLASH code. We examine the dependence of our results on the equation of state used. We also study the influence of rotation on the critical luminosity. Rotation provides additional large-scale, non-radial motion of the sort Hanke et al. suggest is critical to increasing dwell times in the gain region and, hence, increasing the neutrino heating efficiency.

436.09 – **Intermediate-Luminosity Red Transients**

Howard E. Bond[1], R. M. Humphreys[2], L. R. Bedin[3], A. Bonanos[4], K. Davidson[2], B. Monard[5], J. Prieto[6], F. Walter[7]

[1]*STScI,* [2]*U Minnesota,* [3]*Osservatorio di Padova, Italy,* [4]*National Observatory of Athens, Greece,* [5]*Bronberg Observatory, South Africa,* [6]*Princeton U,* [7]*Stony Brook U.*

9:00 AM - 2:00 PM

Intermediate-luminosity red transients (ILRTs) are a recently recognized class of stellar eruptions with maximum luminosities between those of classical novae and supernovae. During their outbursts, which generally last a few months, they typically evolve to extremely red colors, completely unlike novae. Prototypes include the M31 "Red Variable" of 1988, V838 Mon, SN 2008S, V1309 Sco, the M99 optical transient of 2010, and the 2008 and 2010 ILRTs in the nearby spiral NGC 300. I will present recent developments in the study of ILRTs. At present, it appears that there are (at least) two separate evolutionary channels leading to ILRT outbursts: mergers of close binaries (accounting for ILRTs in old populations and possibly V838 Mon), and eruptions on stars of about 8-12 Msun, possibly due to electron-capture SNe (accounting for ILRTs in young populations).

436.10 – **Himalayan Chandra Telescope Observations of Type-Ia Supernova SN 2010at**

Brandon Patel[1], G. Anupama[2], D. K. Sahu[2]

[1]*Rutgers University,* [2]*Indian Institute of Astrophysics, India.*

9:00 AM - 2:00 PM

We present BVRI photometry and spectroscopy of Type Ia Supernova SN 2010at. SN 2010at is located in the MCG+13-09-010 galaxy (z =0.04) and was discovered on 03-19-2010. Our analysis focuses on the follow up observations taken with the 2-meter Himalayan Chandra Telescope from 2010-03-21 to 2010-05-24. We present the light curve and color evolution of SN 2010at, along with MLCS2k2 and SALT-II light curve fits. We find that SN 2010at's color and photometric evolution are similar to SN 1999ac, but SN 2010at is brighter at maximum. Spectroscopically, SN 2010at appears to be normal at early times.

This work was funded by the National Science Foundation's Office of International Science and Education, Grant Number 0854436: International Research Experience for Students, and managed by the National Solar Observatory's Global Oscillation Network.

436.11 – **Crab Nebula Gamma-ray Flares as Relativistic Reconnection Minijets**

Eric Ryan Clausen-Brown[1], M. Lyutikov[1]

[1]*Purdue University.*

9:00 AM - 2:00 PM

We present an analytic statistical model of relativistic magnetic reconnection outflows (``minijets") that can describe the Crab Nebula gamma-ray light curve, including the multiple ~ week-long flares observed by the AGILE and Fermi/LAT satellites. We argue that the flares' unusually short duration, high luminosity, and high photon energies suggest the flare emission regions are moving toward Earth at bulk relativistic speeds, consistent with reconnection minijets. We show that electrostatic acceleration in the

reconnecting region can efficiently accelerate particles up to the radiation reaction limit to produce a mono-energetic synchrotron spectral energy distribution. The statistics of observed minijet high energy fluxes and timescales are assumed to be strongly influenced by their Doppler factors. For statistically independent minijets, we find analytical expressions for all of the moments of the high energy nebular light curve (time average, variance, skewness, etc.). The short timescale variability of the nebula displays a power spectrum with index -2. In the limit of a low reconnection event rate, the observed flare high energy flux distribution follows a power-law of index ~ -1, implying that the flare high energy flux average is dominated by bright rare flares. Thus, we provide a simple minijet statistical model of the Crab Nebula light curve that can be directly compared with gamma-ray observations.

436.12 – **The Crab Pulsar Observed by RXTE: Monitoring the X-ray to Radio Delay for 16 Years**

Arnold H. Rots[1], K. Jahoda[2]

[1]*Smithsonian Astrophysical Observatory,* [2]*NASA/Goddard Space Flight Center.*
9:00 AM - 2:00 PM

The primary pulse of the Crab pulsar at X-ray energies precedes its radio counterpart by about 0.01 period in phase, or approximately 330 microseconds.

In 2004 we published the results of 8 years of monitoring the pulsar by RXTE (Rots, Jahoda, & Lyne 2004, ApJ 605, L129). At the time we could not establish unambiguously whether the delay is in phase or due to a difference in pathlength.

At the end of 2011 we will have twice the time baseline that we had in 2004 and we will present the same analysis, but now over a period of 16 years - which will represent the full mission and the best that will be available from RXTE. Hopefully, the results will allow us to answer the question definitively.

This work is supported by NASA contract NAS8-03060 (CXC).

436.13 – **Young Neutron Stars in Extragalactic Supernovae**

Nathan Tehrani[1], D. R. Lorimer[1]

[1]*West Virginia University.*
9:00 AM - 2:00 PM

Pulsars are compact remnants of stellar cores left behind by supernova explosions. They spin rapidly and emit electromagnetic radiation from their magnetic poles, and gradually lose rotational energy. This project tests and expands upon a previous prediction by Perna et al. for the initial spin rates of neutron stars by attempting to model the x-ray emission from extragalactic supernovae. A computer simulation generated a set of pulsars of known initial rotational periods, magnetic field strengths, and ages, and will calculate the expected x-ray luminosities from the known relationship between magnetic field strengths, slow-down rates, and radio luminosities. This experiment expanded upon the original research by incorporating variability in the angle between the magnetic and rotational axes of each pulsar as well as the braking index value, which in the original publication were kept constant. This examines the effect of the angle on pulsars' x-ray luminosities. The simulated x-ray luminosities were compared to the known x-ray luminosities of known supernova explosions, which served as an upper limit to determine the highest possible initial rotation speeds.

Funding was provided through the WVU Summer Undergraduate Research Program.

436.14 – **Full 3-D MHD Simulations of Accretion Flow in Cataclysmic Variables With Strong and Complex Magnetic Fields**

Paul A. Mason[1], A. G. Zhilkin[2], D. V. Bisikalo[3]

[1]*Univ. Of Texas at El Paso,* [2]*Institute of Astronomy RAS, Chelyabinsk State University, Russian Federation,* [3]*Institute of Astronomy RAS, Russian Federation.*
9:00 AM - 2:00 PM

We performed 3-D MHD calculations of stream accretion in magnetic cataclysmic variable stars (mCVs). Specifically, we simulate accretion flow onto a white dwarf possessing a strong and complex magnetic field which dominates the accretion flow and prevents the formation of an accretion disk. These calculations are motivated by observations that some polars possess non-dipolar magnetic fields. We assume a dipole plus quadrupole field configuration to perform simulations of ten polars, where the only variable is the azimuthal angle of the secondary with respect to the white dwarf. These calculations are also applicable to asynchronous polars, where the spin period of the white dwarf is a few percent different from the orbital period and the structure of one asynchronous polar at ten different spin-orbit beat phases is calculated. We find that for a sufficiently strong quadrupole component an accretion spot occurs near the magnetic equator for slightly less than half of our simulations while a polar accretion zone is active for most of the rest of the simulations. For two configurations; accretion at the dominant polar region and at an equatorial zone occurs simultaneously. We review observational evidence for multi-polar accretion in mCVs and suggest that complex magnetic field structures, including (near) equatorial accretion spots may be evident in some binaries.

436.15 – **The Mass and Wind-momentum Ratios in the Colliding-wind Binary WR140**

Sean M. Dougherty[1], I. A. Smith[2]

[1]*NRC HIA, Canada,* [2]*University of Waterloo, Canada.*
9:00 AM - 2:00 PM

Thirty-six milli-arcsecond resolution VLBA observations of the colliding-wind binary system WR140 reveal the motion of the wind-collision region (WCR) during two orbit cycles. Using orbit parameters derived from optical spectroscopy (Fahed et al. 2011) and orbit inclination deduced from the VLBA observations, the separation of the centre of mass and the WCR is determined through fitting the proper motion of the WCR. This constrains the relationship between mass-ratio and the wind-momentum ratio of the two stars, and constrains the stellar masses in the system.

436.16 – **V458 Vul 2007: A Fast Varying Nova In The Early Phase Of Evolution**

Samira Rajabi[1], M. W. Muterspaugh[1], B. F. Lane[2], M. M. Sirk[3], S. Browne[3], A. Ghasempour[1], S. P. Halverson[4], J. G. Kelly[1], M. Williamson[1]

[1]*Tennesee State University,* [2]*Draper Laboratory,* [3]*University of California,* [4]*The Pennsylvania State University.*
9:00 AM - 2:00 PM

We spatially resolved 2.2 μm emission from the classical nova V458 Vul 2007 using Palomar Testbed Interferometer (PTI) immediately following its discovery on 2007 August 8.54 UT. Simultaneously, we obtained a high resolution spectra of the nova during its early days of explosion. We used several simple morphologies to model the nova's ejecta. Our analysis shows that the emission from the nova can be modeled as a disk at low ellipticity which is consistent to the nova being in the fireball phase at which the outflowing gas is optically thick, confirmed by the presence of strong P-Cygni Balmer lines in the spectra. Combining the expansion velocity derived by Hα line with the nova's angular expansion rate measured with interferometry, the distance to the nova is computed. The computed distance is 9.9 -11.1 kpc. The spectra of the nova unveils the quick transition of the system from Fe II to He/N which makes V458 Vul 2007 a hybrid nova.

436.17 – **Searching For X-ray Emission From AGB Stars**

Rodolfo Montez, Jr.[1], S. Ramstedt[2], J. H. Kastner[1], W. H. T. Vlemmings[3]

[1]*Rochester Institute of Technology,* [2]*Argelander Institute for Astronomy, Germany,* [3]*Onsala Space Observatory, Sweden.*
9:00 AM - 2:00 PM

Polarization of maser emission confirms the presence of magnetic fields in the circumstellar envelopes around stars on the asymptotic giant branch (AGB). Such large-scale fields may be linked to coronal activity above the stellar surface and, hence, may lead to X-ray emission. We have searched the data archives of X-ray satellite observatories for targeted and serendipitous observations of over 500 AGB stars. In addition to the (previously published) targeted observations of Mira, TX Cam, and T Cas, we have identified eight serendipitous observations of AGB stars by the XMM-Newton and Chandra X-ray Observatories. Spurious detections of four AGB stars were made by the XMM Slew survey but are likely due to optical loading. All but Mira are undetected in the remaining observations, from which we derive upper limits to the X-ray fluxes. Two ROSAT faint source catalog entries were found to lie in close proximity to the GALEX-detected AGB stars T Dra and R UMa. As Mira represents the only previously documented case of an AGB star unambiguously detected in X-rays, these two new potential X-ray detections of AGB stars are noteworthy. We present the evidence for X-ray emission from these AGB stars and compare the results of spectral fitting of all three AGB star X-ray sources. We conclude that the origin of the X-ray emission from T Dra and R UMa may be either accretion onto as-yet undetected, but suspected, binary companions, or coronal activity at the AGB stars or putative companions. We also explore the absorbing column density and temperature space which AGB stars might appear as X-ray sources, so as to better understand the dearth of ROSAT detections and evaluate the prospects for future Chandra and XMM detections of AGB stars.

436.18 – **Carbon Monoxide Emission in the Nova V496 Scuti**

Richard J. Rudy[1], R. W. Russell[1], W. L. Dimpfl[1], T. R. Prater[1], L. Bernstein[2], R. C. Puetter[3], R. B. Perry[4], M. L. Sitko[5], K. S. Bjorkman[6], J. P. Wisniewski[7]

[1]*The Aerospace Corporation,* [2]*Spectral Sciences,* [3]*UCSD,* [4]*NASA, LaRC,* [5]*U. of Cincinnati,* [6]*U. of Toledo,* [7]*U. of Washington.*
9:00 AM - 2:00 PM

Infrared spectroscopic data are presented for V496 Scuti (Nova Scuti 2009) that include both the carbon monoxide (CO) fundamental and first overtone emission. These data, from 3 weeks after outburst, were obtained from Lick Observatory and the NASA Infrared Telescope Facility. The relative strength of the bandheads within the first overtone indicates that the CO forms in a region whose temperature is about 2500K. More important, however, is the strength of the first overtone to the fundamental. The flux ratio is about a factor of 20 lower than expected if the fundamental were optically thin. The shape of the CO fundamental, which follows the Planck function at the 2500 K temperature, also indicates that the fundamental is optically thick. To be so means that line escape in this region is controlled by the local thermal width of the lines rather than the overall Doppler widths of the nova ejecta. Despite the optical depth, the energy

radiated by the CO bands is greater than any other infrared line, and is the dominant cooling source for the region in which it forms.

The first overtone also shows a significant contribution from $C^{13}O^{16}$, indicating a C^{13}/C^{12} ratio of about 0.8. C I and O I lines appear in the spectrum along with the CO emission and are also quite strong. While this would suggest that carbon monoxide formation in V496 Scuti did not proceed to saturation (as it does in the outer atmospheres of late-type stars), the comparatively low temperature indicated for the CO molecules suggests that CO formation probably occurs in a different region from that where the C I and O I lines form. The conditions within the CO region should be conducive to dust formation.

Astronomy at The Aerospace Corporation is funded by the Internal Research and Development program.

436.19 – **Discovery of Three New B[e] Supergiants in the Small Magellanic Cloud**

Andrew Graus[1], J. B. Lamb[1], M. S. Oey[1]

[1]*University of Michigan.*
9:00 AM - 2:00 PM

We present the discovery of three new B[e] supergiants (SgB[e]) in the Small Magellanic Cloud (SMC). All three stars (R15, R38, and R48) were identified in the course of our Runaways and Isolated O Type Star Spectroscopic Survey of the SMC (RIOTS4). The stars show optical spectra that closely resemble those of previously known B[e] stars, presenting numerous forbidden emission lines such as [Fe II] and [Si II], and low ionization permitted metal lines such as Fe II. Furthermore, our stars have luminosities of $\log(L/L_\odot) > 4$, and at least two of the three stars show P Cygni profiles in Balmer recombination lines, demonstrating that they are supergiants. However, we find lower infrared excesses and weaker forbidden emission lines than for previously identified B[e] supergiants. This suggests that our stars have less material in their circumstellar disks than other SgB[e] stars, or that the circumstellar material has a lower metallicity than previously identified SgB[e] stars. Our scenario is supported by the fact that the SMC is of lower metallicity than either the Large Magellanic Cloud or the Galaxy, which implies lower circumstellar dust content. Funding for this project was provided by NSF grant AST-0907758.

437 – YSOs, the ISM and Other Topics

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

437.01 – **The Chemical Structure of Orion KL: A 2D Spectral Line Survey at 1mm**

Nuria Marcelino[1], J. Cernicharo[2], G. B. Esplugues[2], A. Palau[3], T. Bell[2], B. Tercero[2], M. Guelin[4]

[1]*National Radio Astronomy Observatory,* [2]*CAB. INTA-CSIC, Spain,* [3]*CSIC-IEEC, Spain,* [4]*IRAM, France.*
9:00 AM - 2:00 PM

The Orion KL nebula is the prototype of high-mass star forming region and one of the best studied regions in our galaxy. Many spectral line surveys of this region have been performed over the last 20 years, revealing a spectacularly prolific line spectrum. The molecular inventory of Orion KL, which includes complex molecular species, is the result of the interaction of the newly formed stars with their environment and grain mantle evaporation. However the chemical complexity of Orion cannot be completely understood without the study of its spatial distribution.

After the completion of the spectral line survey of Orion-IRc2 in the full frequency domain of the IRAM 30m telescope (80-280 GHz), we started a mapping line survey at 1mm over a region 2x2' around Orion-IRc2. With the 9-11" beam size of the 30m telescope at 1mm, the different components of Orion (Extended and Compact Ridge, Hot Core, and Plateau) can be resolved, and a deep view of the physical and chemical conditions of the cloud as a function of position can be obtained. In this poster we present the first results of this 2D line survey (200-250 GHz completed to date). The data reveal the different emission distributions and peak positions depending on the observed molecular species, providing important clues to its chemical formation pathways.

By obtaining a systematic view of the spatial distribution of the molecular emission in Orion, we will be in the best conditions to improve our understanding of the physics and chemistry of high-mass star forming regions. The combination of the IRAM surveys with Herschel/HIFI data from the Guaranteed Time Key Program ``Herschel observations of EXtra-Ordinary Sources (HEXOS)", and its possible use as zero spacing data for future interferometric observations (e.g. with IRAM PdBI or ALMA), demonstrates the legacy nature of this still on-going project.

437.02 – **Aperture Synthesis Observations Toward The Protostellar Systems L1551 Irs 5 And Hl Tau: Rotation In The Infalling Envelope**

Masao Saito[1], Y. Kitamura[2], M. Momose[3], T. Tsukagoshi[4], R. Kawabe[5]

[1]*National Astronomical Observatory of Japan, Japan,* [2]*Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan,* [3]*College of Science, Ibaraki University, Japan,* [4]*Institute of Astronomy, Faculty of Science, University of Tokyo, Japan,* [5]*Nobeyama Radio Observatory, National Astronomical Observatory of Japan, Japan.*
9:00 AM - 2:00 PM

We present aperture synthesis observations of 13CO (J=1-0 and 2-1) emissions toward the low-mass protostellar binary, L1551 IRS 5 and the low-mass single protostar HL Tau, conducted with the Nobeyama Millimeter Array. The purpose of these observations is to reveal the dense envelope structure particularly rotational structure which is a key to understanding formation of single and binary stars. Since both L1551 IRS 5 and HL Tau were born in the Lynds 1551 Dark Cloud, they formed in a similar interstellar environment. Combined with the past data, our 13CO (J=1-0) data have revealed that both the protostars are surrounded by a 1000-AU scale dense envelope perpendicular to the jet/outflow, presumably infalling to the star/disk system. In contrast, a rotating motion is dominant in the envelope of L1551 IRS 5 in 13CO (J=2-1) while a prominent rotating motion is not discerned in the envelope of HL Tau in 13CO (J=2-1). Our results show that local specific angular momenta of the dense envelope around L1551 IRS 5 and HL Tau is roughly constant and that of L1551 IRS 5 is larger by nearly an order of magnitude than that of HL Tau. This observational fact suggests that a dense core rotating fast initially tends to form a binary system as predicted by theoretical studies. Furthermore, since the specific angular momentum is roughly constant in the infalling envelope over a factor of 10 in size, we suggest that the initial rotating structure of the dense core forming L1551 IRS 5 is not a solid body rotations rather faster rotation in the inner region.

437.03 – **Infrared Variability of Protoplanetary Disks: Signs of Complex Disk Structure**

Kevin M. Flaherty[1], J. Muzerolle[2], G. Rieke[1], R. Gutermuth[3], Z. Balog[4], W. Herbst[5], S. Megeath[6], M. Kun[7]

[1]*University of Arizona,* [2]*STSCI,* [3]*University of Massachusetts,* [4]*MPIA, Germany,* [5]*Wesleyan University,* [6]*University of Toledo,* [7]*Konkoly Observatory, Hungary.*
9:00 AM - 2:00 PM

Circumstellar disks around newly formed stars are the sites of planet formation, and their structure can have a large influence on the formation and early evolution of planets. We have obtained multi-wavelength multi-epoch infrared observations of the IC348 cluster, focusing on six transition disks, to look for rapid changes in the structure of these systems. These measurements include optical, near-infrared and mid-infrared spectra, along with intensive mid-infrared photometry covering timescales of days to years. We find that ~70% of the stars with disks are variable, with infrared fluctuations up to a few tenths of a magnitude on timescales of days to weeks. The transition disks, characterized by an SED that indicates clearing of the inner disk, display a 'seesaw' behavior in which the short-wavelength (<8μm) flux and the long-wavelength (>8μm) flux vary in opposite directions by as much as 60% in as little as one week. Our observations show that this can be explained by varying the scale height of the inner disk. We can rule out accretion and disk winds, leaving an embedded planet or a dynamic magnetic field as the likely physical source of the disk perturbation.

437.04 – **Evidence For Accretion-driven X-ray Production In Ex Lupi And V1647 Ori**

William K. Teets[1], D. Weintraub[1], N. Grosso[2], D. Principe[3], J. Kastner[3], K. Hamaguchi[4], M. Richmond[3]

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9:00 AM - 2:00 PM

EX Lupi is the prototype for a class of young, pre-main sequence stars, which are observed to undergo irregular optical outbursts that result in a several magnitude rise of the optical flux. EX Lupi was observed to optically erupt in 2008 January, triggering Chandra X-ray Observatory ToO observations shortly thereafter. In the 2008 March and June observations, we find the X-ray spectrum is best modeled with a two-temperature plasma with components of ~0.4 and ~1.7 keV. In subsequent observations in 2008 October, the lower-temperature plasma component appears to fade as EX Lupi returns to more quiescent optical levels. Accretion hotspots should generate plasma with temperatures of a few million Kelvin (~0.3 keV); thus, this fading of the lower-temperature component in the spectra of EX Lupi is consistent with a decrease in accretion-generated X-ray flux from shock-heated plasma. We also find that during optical outburst, the light curve of EX Lupi appears to exhibit periodic variability of ~37 days with the V-band flux changing by as much as ~4 magnitudes.

Similar to EX Lupi, V1647 Ori is a low-mass, deeply-embedded, pre-main sequence star

that has undergone two optical/NIR outbursts in the last decade; both times, the star gradually faded over several months to years. The X-ray evolution during each of these eruptions has been monitored through multi-epoch Chandra observations. Like the X-ray flux of EX Lupi, we find that the X-ray flux of V1647 Ori is well correlated with the rise and fall in the optical and infrared brightnesses for both epochs; unlike EX Lupi, however, these spectra are well modeled with a single-temperature plasma of 4-6 keV. These results suggest that the primary X-ray generation mechanism for this star during optical/NIR outbursts is accretion but that the X-ray flux is likely generated by magnetic reconnection events in the accretion stream.

437.05 – **Mid-Infrared Variability of Orion Protostars**

S. Terebey[1], J. Stauffer[2], M. Morales[2], H. H. M. Mok[1], D. Padgett[3], L. Rebull[2], P. Plavchan[2]

[1]*Cal. State Univ. at Los Angeles,* [2]*Caltech,* [3]*NASA Goddard.*

9:00 AM - 2:00 PM

We present results for Class I protostars in Orion based on synoptic data from the YSO variability (YSOVAR) program. The mid-infrared data include Spitzer data at 3.6 and 4.5 microns wavelength representing high and low cadence measurements at hour, day, and year time scales in the Orion star-forming region. The mid-infrared data are sensitive to the inner regions of disks and thus provide information on inner disk structure and variable accretion rates. Protostars show little variation over one day but exhibit significant variations over several days. The typical magnitude variation is 0.3 mag, small enough to suggest that hot spot plus disk models developed for class II sources may also apply to protostars. However about 10 percent of Orion protostars show variations greater than 0.6 magnitudes. We discuss several models that can produce large magnitude variations in protostars.

437.06 – **Spatially Resolved H2 Emission In The GG Tau A Binary System**

Jeffrey S. Bary[1], T. L. Beck[2], A. Dutrey[3], S. Guilloteau[3], V. Pietu[4]

[1]*Colgate University,* [2]*Space Telescope Science Institute,* [3]*Laboratoire d'Astrophysique de Bordeaux, France,* [4]*IRAM, France.*

9:00 AM - 2:00 PM

We present a high-resolution image of molecular hydrogen emission from the GG Tau A binary system. Using NIFS+AO on Gemini North to achieve ~0.1" resolution, we clearly resolve the emitting gas to be located within the unstable region between the stellar cores and the circumbinary ring. The brightest arc of H2 emission observed to the northeast of the companions closely aligns with the location of a accretion "streamer" suggested by the high resolution millimeter observations presented in Pietu et al. 2011. The proximity of the H2 emission to the infalling streamer strongly suggests that the H2 emission is the result of a shocked gas residing in the orbital environment of the stellar companions. Near-infrared H2 line ratios predict an excitation temperature on the order of 1700 K and are compared to standard shock models.

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438 – Star Associations & Clusters

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

438.01 – **F Turnoff Distribution in the Galactic Halo Using Globular Clusters as Proxies**

Matthew Newby[1], H. J. Newberg[1], J. Simones[2], M. Monaco[1], N. Cole[3]

[1]*Rensselaer Polytechnic Institute,* [2]*University of Minnesota, Minneapolis,* [3]*Johns Hopkins University.*

9:00 AM - 2:00 PM

F turnoff stars are important tools for studying Galactic halo substructure because they are plentiful, luminous, and can be easily selected by their photometric colors from large surveys such as the Sloan Digital Sky Survey (SDSS). We describe the absolute magnitude distribution of color-selected F turnoff stars, as measured from SDSS data, for eleven globular clusters in the Milky Way halo. We find that the absolute magnitude distribution of turnoff stars is intrinsically the same for all clusters studied, and is well fit by two half Gaussian functions, centered at $\mu = 4.18$, with a bright-side $\sigma = 0.36$, and with a faint-side $\sigma = 0.76$. However, the color errors and detection efficiencies cause the observed σ of the faint-side Gaussian to change with magnitude due to contamination from redder main sequence stars (40% at 21st magnitude). We present a function that will correct for this magnitude-dependent change in selected stellar populations, when calculating stellar density from color-selected turnoff stars. We also present a consistent set of distances, ages and metallicities for eleven clusters in the SDSS Data Release 7. We calculate a linear correction function to Padova isochrones so that they are consistent with SDSS globular cluster data from previous papers. We show that our cluster population falls along the theoretical Age-Metallicity Relationship (AMR), and further find that isochrones for stellar populations on the AMR have very similar turnoffs; increasing metallicity and decreasing age conspire to produce similar turnoff magnitudes and colors for all old clusters that lie on the AMR.

This research was supported by NSF grant AST 10-09670 and the NASA/NY Space Grant.

438.02 – **Exploring the Outer Halo Globular Cluster Pyxis**

Brian L. Pohl[1], B. W. Carney[1]

[1]*University of North Carolina, Chapel Hill.*

9:00 AM - 2:00 PM

Discovered in 1995, Pyxis is one of the most poorly studied globular clusters in the outer halo of the Milky Way. To further probe this cluster, we present the first color magnitude diagram calibrated to the Johnson BV system. We obtained nearly fifteen hours of data over the course of eleven nights between 2007 and 2009 using the SOAR telescope. Our final CMD has internal errors of 0.025 at V = 24. We use the CMD to determine the extinction, metallicity, distance and age of this cluster.

438.03 – **NGC 2146: a Nearby Laboratory for Cluster Formation Modes**

Angela Adamo[1], J. S. Gallagher[2], L. Smith[3], M. Westmoquette[4], I. S. Konstantopoulos[5], N. Bastian[6], J. E. Ryon[2], E. Zackrisson[7], S. S. Larsen[8], J. Charlton[5], D. Weisz[9]

[1]*Max-Planck-Institut Fuer Astronomie, Germany,* [2]*University of Wisconsin-Madison,* [3]*Space Telescope Science Institute and European Space Agency,* [4]*European Southern Observatory, Germany,* [5]*Penn State,* [6]*Excellence Cluster Universe, Germany,* [7]*Oscar Klein Center, Astronomy Department, Stockholm University, Sweden,* [8]*Astronomical Institute, Utrecht University, Netherlands,* [9]*University of Washington.*

9:00 AM - 2:00 PM

As part of the Snapshot Hubble U-band Cluster Survey (SHUCS), we present the first complete study of the star cluster population in NGC 2146. NGC 2146 is a spectacular nearby starburst galaxy, which has experienced a recent merger event. The high-resolution cameras onboard the Hubble Space Telescope have produced a superb imaging dataset for this galaxy. The tidal streams and some starburst regions in the edge-on disk are already visible in the ultra-violet and B bands. However, only the longer wavelengths, such as R, I, and the near-infrared bands, can penetrate the dust screen and reveal the complexity of the starburst operating in the central regions. Several hundreds of star clusters have been detected. We have performed a detailed analysis of the spectral energy distributions of the clusters to constrain age, mass, and extinction of the entire population. These properties are used to map the starburst propagation in the galaxy and to understand how diverse galactic environments affect cluster formation. The most massive clusters are observed in the central starburst region, likely produced by the gas compression during the merging phase. In the tidal stream, where the extinction is low, star and cluster formation has happened in a less dense environment. The presence of numerous HII regions and clusters with ages of a few tens of Myr proves that star formation in the tidal stream has recently taken place. Several cluster complexes have been found in the disk, with age spreads not larger than 10 Myr. The cluster complexes in the disk differ from those in the stream in that they are more compact and probably formed in a single starburst episode. Finally, we observe several globular clusters located in the galactic halo.

Research based on observations obtained with the NASA/ESA Hubble Space Telescope through program IDs 12229 and 12206.

438.04 – **WIYN Open Cluster Study: Spectroscopic Metallicity of the Open Cluster M37**

Evan Losh[1], M. Gregor[1], D. Gole[1], A. Steinhauer[1], C. P. Deliyannis[2]

[1]*SUNY Geneseo,* [2]*Indiana University.*

9:00 AM - 2:00 PM

M37 is a very rich open cluster at an age that is slightly younger than the Hyades which places it in a key position to diagnose important issues in stellar evolution such as the Lithium Gap. We present high-resolution, WIYN Hydra spectroscopy of 20 dwarfs in the Open Cluster M37 and report a cluster [Fe/H].

438.05 – **FUV & NUV Integrated-Light Photometry of Galactic Globular Clusters Using GALEX Archival Data.**

Cesar A. Munoz Gonzalez[1], P. Pessev[2], R. de Propris[3]

[1]*University of Concepcion, Chile,* [2]*Gemini Observatory, Chile,* [3]*Cerro Tololo Inter-American Observatory, Chile.*

9:00 AM - 2:00 PM

We developed an Integrated-light photometric database in the far (1500 Angstrom) and near (2300 Angstrom) ultraviolet, covering a big data set the Galactic Globular Clusters (GGCs) available in the GALEX GR6 data release. The dataset includes 40 objects, spanning a wide range of stellar population properties. We performed curve of growth

and King model fitting on the FUV and NUV images to obtain total magnitudes in these two passbands. Together with existing optical and infrared integrated photometry, age and metallicity estimates available from the literature, this constitutes an important multi-wavelength empirical dataset to compare with unresolved old stellar populations (GCs in distant galaxies). This is the first extension of the integrated-light measurements of old stellar populations in the Far-UV spectral domain. The UV data provide an unique opportunity to test and improve the Simple Stellar Populations (SSP) model performance in this part of the spectrum (e.g. the influence of blue and extreme HB stars and blue stragglers on integrated photometry and spectroscopy).

438.06 – **Wiyn Open Cluster Study: UBVRI CCD Photometry of the Open Cluster NGC 581**

Gole Daniel[1], E. Losh[1], M. Gregor[1], A. Steinhauer[1], C. P. Deliyannis[2]

[1]*SUNY Geneseo,* [2]*Indiana University.*

9:00 AM - 2:00 PM

We present WIYN 0.9m UBVRI photometry of NGC 581, a young, metal rich open cluster. We report derived values for the cluster age, distance, reddening.

438.07 – **The Star Cluster Population of the Interacting Galaxy System Arp 261**

Bradley W. Peterson[1], C. Struck[1], B. J. Smith[2], M. Hancock[3]

[1]*Iowa State University,* [2]*East Tennessee State University,* [3]*University of California.*

9:00 AM - 2:00 PM

We examine the effects of galaxy interactions on star formation by studying the star cluster population of the interacting galaxy system and Arp 261, using data from the Hubble Space Telescope along with ancillary data from Spitzer Space Telescope and Galaxy Evolution Explorer (GALEX) to obtain broader wavelength coverage. Combined with Starburst99 evolutionary synthesis models, we estimate the ages and masses of the clusters. The mass and luminosity distributions are found to be in good agreement with other systems from the literature.

The age distribution of the Arp 261 cluster population is more difficult to interpret because the metallicity of the galaxies is currently unknown, making the ages highly uncertain. Analysis of optical spectra, will allow us to determine the metallicity of the galaxies and improve our estimates of the cluster ages. Despite the uncertainties, it is clear that the majority of the clusters have ages ~ 20 Myr or less. We also find more evidence that large “clumps” of clusters, the smallest scale of star formation directly observable with Spitzer and GALEX, tend to have older ages than the individual clusters they contain, possibly indicating that the young clusters we detect are surrounded by their dispersed predecessors. We call this the “jewels in the crown” effect.

The cluster age distributions in the features of this system have significant implications for its dynamical history. Radio data from the NVSS already indicates that the hydrodynamical Taffy-like collision scenario suggested by the optical morphology may not be correct. Cluster ages in the northern bridge could provide support for this conclusion if the clusters are young enough to have formed in situ. The tidal interactions of a tidal flyby, in contrast, would be expected to displace older populations from the disks, so the bridge would include older clusters.

438.08 – **Spitzer IRAC Mid-IR Photometry of Gallactic Globular Clusters.**

Peter Pessev[1], P. Goudfrooij[2], T. Puzia[3], R. Chandar[4]

[1]*Gemini Observatory, Chile,* [2]*STScI,* [3]*Pontificia Universidad Catolica de Chile, Chile,* [4]*University of Toledo.*

9:00 AM - 2:00 PM

We present the first photometric results from a program to obtain Mid-IR photometry for a sample of 18 Gallactic Globular clusters. The objects in our sample span a wide parameter space in terms of stellar populations, structural parameters and Galactic coordinates, constituting a fundamental dataset to study old stellar populations in the Mid-IR and a benchmark for the Stellar Population Models in the Mid-IR. The importance of these models is going to increase in the light of the upcoming Mid-IR space-based telescopes (Spica and JWST). The current sample could also be used as a template to study old, metal-poor stellar populations. It is complemented with literature data to provide multi-wavelength Spectral Energy Distributions (SEDs) of the objects.

438.09 – **A uvbycaHB CCD Survey Of The Intermediate-age Open Cluster, NGC 7789**

Bruce A. Twarog[1], B. J. Anthony-Twarog[1], B. S. Schafer[1]

[1]*Univ. of Kansas.*

9:00 AM - 2:00 PM

The 1.4 Gyr-old open cluster, NGC 7789, has been surveyed and analyzed using CCD photometry on the extended Stromgren system. Using a preliminary calibration of the intermediate-band indices, 122 highly probable F-dwarf single-star members from the core of the cluster produce $E(b-y) = 0.214 \pm 0.010$ (zero-point uncertainty included) or $E(B-V) = 0.293 \pm 0.014$. The metallicity based upon hk and m_1 as a function of Hβ is [Fe/H] = -0.03 ± 0.03, effectively solar. While the photometry will be used as a key component within a high-dispersion spectroscopic study of the turnoff and giant branch members, the precise photometry of the red giants reveals that within the very rich red clump, stars known to be single from radial-velocity surveys exhibit higher m_1 and hk indices with increasing luminosity, indicating a potential change in the overall metallicity tied to elements other than Fe.

438.10 – **Determination of a Precise Age of the Old Open Cluster Berkeley 39 from the Eclipsing Binary**

Emily Martin[1], E. Sandquist[1], C. Gonzalez[1], M. Shetrone[2], J. Orosz[1]

[1]*San Diego State University,* [2]*McDonald Observatory, University of Texas.*

9:00 AM - 2:00 PM

We obtained photometry from the Mount Laguna Observatory 1 meter telescope and the radial velocities using the 9 meter Hobby-Eberly Telescope to perform a study of the partially eclipsing binary star V15 in the old (~6 Gyr) open star cluster Berkeley 39. Eclipsing binaries can often provide the opportunity to measure stellar masses and radii to a precision of 1%, and when one of the stars is evolving, a precise radius measurement can lead to a precise age determination (10% or better). The more massive star in the binary is on the subgiant branch and rapidly evolving, which will allow us to provide a precise new determination of the age of Berkeley 39. The fainter star in the binary has almost the same mass as the Sun, which can give us an idea of what the Sun will look like in 1-2 Gyr. We gratefully acknowledge support from The National Science Foundation for E.J.M as part of the REU program at San Diego State University under grant AST-0850564 and to E.L.S under grant AST-0908536.

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439 – Stellar Topics

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

439.01 – **Standard Star System for Intermediate-band CaH Photometry: SARA U42a and U55 Data**

Laurel Farris[1], C. Spengler[2], T. Robertson[3]

[1]*Missouri State University,* [2]*Case Western Reserve University,* [3]*Ball State University.*

9:00 AM - 2:00 PM

Multicolor CCD observations of red stars have been made over the past fifteen years with different telescopes, filters and camera systems. The purpose of this study was to develop a more efficient way of putting all the data onto the same standard photometric system. A calcium hydride filter was also used as a discriminator between red giants and red dwarfs, and standard values for the R-L (CaH) color index were calculated. A brief description of the different transformation methods is provided, focusing on transforming data from the U55 (R-L) system to the U42a system. Results from each system were compared to ensure the accuracy of these methods. Values from the U55 system proved to be essentially the same as those for the U42a system.

Subject headings: Photometry, standard system

This project was funded by the National Science Foundation Research Experiences for Undergraduates (REU) program through grant NSF AST-1004872. More information on the AASTeX macros package are available at http://ucpjournals.uchicago.edu /AAS/AASTeX/.

439.02 – **Self-Similar Dynamics of SNe Ejecta**

Lile Wang[1]

[1]*Tsinghua University, China.*

9:00 AM - 2:00 PM

With proper physical mechanisms of energy and momentum input from around the centre of a self-gravitating polytropic gas sphere, a central spherical "void" or "cavity" or "bubble" of very much less mass contents may emerge and then dynamically expand into a variety of surrounding more massive gas envelopes with or without shocks. We explore self-similar evolution of a self-gravitating polytropic hydrodynamic flow of spherical symmetry with such an expanding "void" embedded around the center. The void boundary supporting a massive envelope represents a pressure-balanced contact discontinuity where drastic changes in mass density and temperature occur. We obtain numerical void solutions that can cross the sonic critical surface either smoothly or by shocks. Using the conventional polytropic equation of state, we construct global void solutions with shocks travelling into various envelopes including static polytropic sphere, outflow, inflow, breeze and contraction types. In the context of supernovae, we discuss the possible scenario of separating a central collapsing compact object from an outgoing gas envelope with a powerful void in dynamic expansion. Initially, a central bubble is carved out by an extremely powerful neutrinosphere. After the escape of neutrinos during the decoupling, the strong electromagnetic radiation field and/or electron-positron pair plasma continue to drive the cavity expansion. In a self-similar dynamic evolution,

the pressure across the contact discontinuity decreases with time to a negligible level for a sufficiently long lapse and eventually, the gas envelope continues to expand by inertia. We describe model cases of polytropic index $\gamma=4/3-\varepsilon$ with $\varepsilon>0$ and discuss pertinent requirements to justify our proposed scenario.

439.03 – **Brown Dwarfs Around Extrasolar Planet Systems**

John Bent[1], J. Carson[1], M. Marengo[2], T. Henning[3], W. Brandner[3], M. Feldt[3], C. Schnupp[3]

[1]*College of Charleston,* [2]*Iowa State University,* [3]*Max Planck Institute for Astronomy, Germany.*

9:00 AM - 2:00 PM

Orbital dynamics models predict that the unusually high eccentricities of radial velocity planets can be explained by a high frequency of wide separation (100 AU to a few thousand AU) brown dwarfs. Using a combination of Spitzer IRAC archival data and J-band data from the Calar Alto 3.5m Telescope, we are observationally exploring this question by carrying out an imaging search around several dozen radial velocity planet systems. Wide separation companion populations are being explored via their unique positions on IRAC-band/J-band color-color plots. The integration of the new J-band data with the IRAC archival data enables an improvement in companion detection sensitivities by > 2 magnitudes (at 4.5 micron), compared to previous searches with IRAC data alone. This equates to a 5-fold improvement in the number of classifiable field objects, and a sensitivity to brown dwarfs or planets as cold as ~700K (late-T or Y-dwarf), as opposed to ~1500K for previous searches around these targets. Accompanying Monte Carlo population analyses are being implemented to determine search completeness levels as well as the likelihood of a given wide-separation companion population being consistent with the observational results.

439.04 – **Emission Line Variability In The HgMn Star 11 Per**

Glenn Michael Wahlgren[1], D. Bohlender[2], M. Melendez[3]

[1]*NASA Headquarters / CUA,* [2]*NRC Herzberg Institute of Astrophysics, Canada,* [3]*University of Maryland.*

9:00 AM - 2:00 PM

High spectral resolution observations of the HgMn star 11 Per (HD 16727, B7p) have revealed temporal variability in weak emission lines of Mn II. The observations were obtained on three epochs (JD 2455549.728, 2455555.800, 2455560.693) with the CFHT ESPaDOnS instrument during December 2010, and were complemented with an earlier epoch (JD 2452514.623) NOT SOFIN observation and a spectrum obtained with the CFHT Gecko instrument (JD 2451420.641, presented in Wahlgren & Hubrig 2000, A&A 362, L13). Lines of Mn II multiplet 13 (6120 - 6135 A) are observed in emission at each epoch, but their observed intensities are not in relative proportion to their respective gf-values. The intrinsically strongest line, the J(lower) = 4 to J(upper) = 5 transition at 6122.434A is observed to be a simple emission line on JD 5549 and JD 5560, while on JD 5555 and the two earliest epochs its appearance is that of a P Cyg profile with absorption component on the red side of the line profile. The similar appearance of Mn II multiplet 11 on JD 5549 and JD 5555, along with the similar appearing spectra at the three other epochs suggest that the variability may be rotationally modulated. For main sequence stars of spectral type B5 to B9, the stellar radius ranges from 7 to 2.5 solar radii, respectively, which along with an upper limit of the rotational velocity (v = vsin(i) = 5 km/s, Wahlgren & Hubrig) leads to the determination of a range in the rotation period of approximately 70 to 25 days. This range is greater than the difference between epochs JD 5549 and JD 5560, where the Mn II lines appear roughly similar. Future high resolution spectral observations obtained at a higher cadence are needed to enable a more accurate determination of the rotation period.

439.05 – **Characterizing the Sites of Hadronic Cosmic Ray Acceleration**

Ylva Pihlstrom[1], R. Mesler[1], L. Sjouwerman[2], D. Frail[2], M. Claussen[2]

[1]*Univ. of New Mexico,* [2]*NRAO.*

9:00 AM - 2:00 PM

It has been argued that supernova remnant (SNRs) shocks are the acceleration sites for galactic cosmic rays. While this has been established for electrons, solid evidence for hadrons constituting the bulk of the cosmic rays have been lacking. Models of hadronic cosmic ray acceleration in SNRs predict a gamma-ray flux density depending on parameters like the environment density and distance. Few reliable estimates of those parameters exist. SNRs with cosmic rays interacting with molecular clouds are expected to be bright gamma-ray sources, and these sites can be traced using 1720 MHz OH masers. The masers give information about the density and kinematical distance estimates. Only 10% of galactic SNRs harbor OH masers, and we have therefore searched for a more frequently occurring SNR/cloud interaction tracer. We have detected 36 GHz and 44 GHz methanol masers associated with a few SNRs. Here we report on the result of a search for methanol masers in 21 SNRs, and in particular the details of our detections in Sgr A East. Combining observations and modeling of methanol masers in SNRs, we aim to better constrain the density and distance to SNRs with TeV emission. The goal is to test the hadronic cosmic ray models and to understand the mechanisms of particle acceleration in SNRs.

This project is supported under NASA-Fermi grant NNX10A055G.

439.06 – **The Lifetime of Protoplanetary Disks Surrounding Intermediate-mass Stars**

Chikako Yasui[1], N. Kobayashi[2], A. T. Tokunaga[3], M. Saito[1]

[1]*National Astronomical Observatory of Japan, Japan,* [2]*Institute of Astronomy, School of Science, University of Tokyo, Japan,* [3]*Institute for Astronomy, University of Hawaii.*

9:00 AM - 2:00 PM

To quantitatively and comprehensively study the lifetime of protoplanetary disks surrounding intermediate-mass stars (~2-6M⊙), we derived intermediate-mass disk fractions (IMDFs) using near-infrared JHK photometric data with a robust method with which the IMDF can be derived with high accuracy. We applied this method to all well-known nearby (D≲3kpc) and young (≲5Myr) clusters. The derived IMDFs appear to approximately follow an exponential decay with the cluster age. From the best fit of the decay curve, the characteristic disk lifetime for intermediate-mass stars is found to be 1.5±0.1Myr with an initial IMDF of 42±10%. The estimated disk lifetime is about half of those for low-mass stars (≈3Myr), showing lifetime is proportional to M*^(-0.5±0.2), where M* is the stellar mass. This dependence is consistent with previous works that qualitatively suggest this dependence. However, we also found that the outer MIR-disk traced by Spitzer 8μm excess have ~3Myr longer lifetime. Because such lifetime offset is not seen for low-mass stars, this may be a special characteristics for intermediate-mass stars. Because ground-based JHK imaging can achieve much higher sensitively with higher spatial resolution to resolve cluster stars than thermal IR imaging (e.g., using L-band or Spitzer MIR bands), our simple method can be applied to distant (D≳3kpc) clusters, enabling the study of environmental dependence of disk lifetime throughout the Galaxy and even for extra-galaxies.

439.07 – **Polycyclic Aromatic Hydrocarbon Processing in the Blast Wave of the Supernova Remnant 132D**

Jeonghee Rho[1], A. Tappe[1]

[1]*SOFIA Science Center/USRA.*

9:00 AM - 2:00 PM

We present Spitzer Infrared Spectrograph 14-36 micron spectral mapping of the entire supernova remnant N132D in the Large Magellanic Cloud. We show a multi-wavelength study of N132D including archival Chandra X-ray and HST optical maps. This case study focuses on the processing of Polycyclic Aromatic Hydrocarbons (PAHs) that were previously identified in the southeastern blast wave of N132D by Tappe et al. 2006. The mid-infrared spectra trace the strong continuum emission and show a unique, nearly featureless hump in the 15 to 20 micron region. We attribute this emission to PAH molecules and show how the typical PAH emission bands observed in the surrounding medium ahead of the blast wave disappear. We present changes in the PAH emission spectra as a function of the distance from the shock front. The featureless PAH hump appears most strongly at the outer edge of the blast wave and coincides with fainter, diffuse X-ray emission that precedes the brightest X-ray and optical filaments. This suggests that PAH molecules in the surrounding medium are swept up and processed in the hot gas of the blast wave shock, where they survive the harsh conditions long enough to be detected. In addition, a broad emission feature at 20 micron appears together with the PAH hump. We speculate that this feature is connected to the processing of PAH molecules or clusters in the blast wave shock. We find a similarity of this feature to the well-known but as of yet unidentified 20.1 micron feature observed in carbon-rich protoplanetary nebulae and our detection might offer new clues for its identification.

439.08 – **Search for High Proper Motion Objects Using WISE and 2MASS**

Philip Castro[1], J. E. Gizis[1]

[1]*University of Delaware.*

9:00 AM - 2:00 PM

By comparing the Wide-field Infrared Survey Explorer (WISE) preliminary data release to the Two Micron All Sky Survey (2MASS) in search of high proper motion objects ($\geq 0.3''\ yr^{-1}$), we find over 200 dwarfs, most being M dwarfs, and a few interesting L dwarfs. Among these, WISEP J060738.65+242953.4 (W0607+2429) is the third closest L dwarf at $7.8^{+1.4}_{-1.2}$ pc, and WISEP J180026.60+013453.1 (W1800+0134) is the seventh closest L dwarf at 8.8±1.0 pc, these two late L dwarfs near the L/T transition double the number of late L dwarfs within 10 pc from two to four. WISEP J004701.06+680352.1 (W0047+6803) is one of the reddest known field L dwarfs with $J-K_S = 2.55\pm0.08$, a prime target for the study of extremely dusty substellar atmospheres. These close L dwarfs provide an opportunity for further study to resolve outstanding issues regarding condensate clouds of low temperature atmospheres near the L/T transition as well as provide insight into the unusually red L dwarf class. This research is supported by the Annie Jump Cannon Fund at the University of Delaware.

439.09 – **A Cautionary Tale: MARVELS Brown Dwarf Candidate Reveals Itself as a Likely Eccentric Binary**

Claude E. Mack[1], J. Ge[2], K. Stassun[1], J. Wisniewski[3], S. Gaudi[4], S. Fleming[5], N. De Lee[6], B. Lee[2], L. Ghezzi[7], G. Porto de Mello[8], L. Ferreira[8], B. Femenia[9], J. Gonzalez Hernandez[9], M. Esposito[9], S. Mahadevan[10], E. Agol[3], B. Tofflemire[3], T. Beatty[4], J. Eastman[4], L. Hebb[1], J. Pepper[1], P. Cargile[1], M. Paegert[1], R. Siverd[1]

[1]Vanderbilt University, [2]University of Florida, [3]University of Washington, [4]Ohio State University, [5]University of Florida, Pennsylvania State University, [6]University of Florida, Vanderbilt University, [7]Observatorio Nacional/LIneA, Brazil, [8]Observatorio do Valongo, Brazil, [9]IAC, Spain, [10]Pennsylvania State University.
9:00 AM - 2:00 PM

The MARVELS (Multi-object APO Radial Velocity Large-area Survey) project will monitor the radial velocities of 3300 stars. As a result, the project is likely to find rare objects, such as brown dwarf (BD) companions in the so-called brown dwarf desert. Two BD candidates in the desert have already been uncovered by the survey. Until recently, MARVELS Candidate 10 (MC10) appeared to be yet another candidate for the desert. The RV data seemed to neatly fit an eccentric orbit with a 237-day period and a minimum mass of 50 Jupiter masses. However, there were two anomalous points in the RV follow-up,

which were initially rejected because they were thought to be a result of changes with the instrument. Then it was discovered that the original MARVELS data possessed similar anomalous points which had also been excluded as outliers. A thorough re-examination of the cross-correlation functions (CCFs) in both data sets revealed that the two anomalous points in the follow-up data had double-peaked CCFs, and the MARVELS data showed CCFs that seemed too broad compared to the other MARVELS candidates. This led to the conclusion that MC10 is most likely an eccentric spectroscopic binary with the long axis aligned nearly perpendicular to the line of sight. Therefore, it is only for a brief moment near periastron that the two radial velocities are large and disparate enough to be resolved as a double-peaked CCF. This cautionary tale implies that RV searches for substellar companions must ensure full phase coverage, and must carefully examine how the CCF changes with time, in order to avoid this kind of astrophysical false positive.

439.10 – **Swift/UVOT Photometry of WeBo 1: Unmasking a Faint Hot Companion Star**

Michael Siegel[1], E. Hoversten[1], H. E. Bond[2]

[1]Pennsylvania State University, [2]Space Telescope Science Institute.
9:00 AM - 2:00 PM

We present an analysis of over 100 ks of data on the planetary nebula WeBo 1 (PN G135.6+01.0) obtained with the Swift Ultraviolet Optical Telescope (UVOT). The central object of this nebula has previously been described as a late-type K giant with a possible hot companion, most likely a young pre-white dwarf. UVOT photometry shows that while the optical photometry is consistent with a large cool object, the NUV photometry shows far more ultaviolet flux than could be produced by any late-type object. Using model stellar atmospheres and a comparison to UVOT photometry for the archetype pre-white dwarf PG1159-035, we find that the companion has a temperature of at least 40,000 K and a radius of, at most, .056 solar radii. We find that higher temperatures more consistent with expectations for a pre-white dwarf can be derived if the foreground dust has a strong "blue bump" at 2175 Angstroms and a lower R_V. Our results demonstrate the ability of Swift to both uncover and characterize hot hidden companion stars and to constrain the UV extinction properties of foreground dust based solely on UVOT photometry

439.11 – **X-ray Spectral Analysis of Dim Type Ia Supernova Remnant Candidates in the Small Magellanic Cloud**

Quentin Roper[1], R. McEntaffer[1], C. DeRoo[1]

[1]University of Iowa.
9:00 AM - 2:00 PM

We report on the statistical analyses of three morphologically asymmetric low-count supernova remnants, designated IKT 5, IKT 25, and DEM S 128 in the Small Magellanic Cloud (SMC). These remnants have been previously identified as Type Ia candidates based on the presumed overabundance of iron in their XMM CCD spectra. We have used archived Chandra data to perform spectral analyses on these three remnants. Their tentative Type Ia designation and morphological asymmetry is in contrast to more recent findings that soft x-ray morphology is generally more symmetric in Type Ia remnants in the Large Magellanic Cloud and Milky Way. We combine the Chandra data with Spitzer data to show that the morphology is affected by complicated environmental interactions with these remnants. Moreover, by performing a maximum-likelihood analysis fitting technique on the soft X-ray spectra of these remnants, we find that these remnants are dominated by surrounding ISM emission, as opposed to being iron ejecta-dominated, as expected for younger Type Ia supernova remnants.

439.12 – **Hubble Space Telescope Detection of Binary Companions Around Three WC9 Stars: WR 98a, WR 104, and WR 112**

Debra J. Wallace[1], M. M. Shara[2], D. R. Gies[3], A. F. J. Moffat[4]

[1]University of South Carolina Beaufort, [2]American Museum of Natural History, [3]Georgia State University, [4]University of Montreal, Canada.
9:00 AM - 2:00 PM

The Wolf-Rayet stars WR 98a, WR 104, and WR 112 are known to form dust either episodically or continuously via colliding wind interactions with close companions at separations ranging from a few AU for WR 98a and WR 104 to ~20 AU for WR 112. We present new *Hubble Space Telescope* (HST) *Wide Field and Planetary Camera 2* (WFPC2) images of the WC9 Wolf-Rayet stars WR 98a, WR 104, and WR 112 that resolve each of these known binary systems into multiple order systems. Wide-band **U**, **B**, and **V** images of WR 104 and WR 112 resolve each into two optical components at a separation of approximately 1". WR 112 also has a likely wide companion 5.6" distant. The **B-V** and instrumental **U-B** colors of the WR 104 optical pair are similar and consistent with a physical relationship. The colors of the close WR 112 optical pair are quite different, but there is an extension of the hot dust surrounding WR 112 in the direction of the optically discovered companions, leaving a physical relationship uncertain. HST wide band **V**, **R**, and **I** imaging of WR 98a resolves this star into a small group of 4 bright stars whose different reddening values also leave the physical relationship between the stars unclear. In each case, we suggest that the companion stars are physically bound companions and that the Wolf-Rayet component is the most reddened object because of heavy circumstellar dust obscuration. This could create a significant color difference between a physically bound companion and the WC9 star.

439.13 – **Yonsei Evolutionary Population Synthesis (YEPS) : The 2012 Version**

Sang-Yoon Lee[1], C. Chung[1], H. Kim[1], S. Yoon[1]

[1]Department of Astronomy and Center for Galaxy Evolution Research, Yonsei University, Korea, Republic of.
9:00 AM - 2:00 PM

We Present a new, year 2012 version of the Yonsei Evolutionary Population Synthesis (YEPS 2012) model for simple stellar populations. The standard YEPS employs the most up-to-date Yonsei-Yale stellar evolutionary tracks and the BaSeL flux libraries. The spectro-photometric model data of the entire parameter space are available at http://web.yonsei.ac.kr.cosmic/data/YEPS.htm

439.14 – **Convection in White Dwarfs**

Judith L. Provencal[1], H. Shipman[1], J. Dalessio[1], M. M[2]

[1]University Of Delaware, [2]University of Texas.
9:00 AM - 2:00 PM

Convection is one of the largest sources of theoretical uncertainty in our understanding of stellar physics. Current studies of convective energy transport are based on the mixing length theory. Originally intended to depict turbulent flows in engineering situations, MLT enjoys moderate success in describing stellar convection. However, problems arising from MLT's incompleteness are apparent in studies ranging from determinations of the ages of massive stars, to understanding the structure F and early A stars, to predicting the pulsation periods of solar stars, to understanding the atmosphere of Titan. As an example for white dwarfs, Bergeron et al. (1995) show that model parameters such as flux, line profiles, energy distribution, color indices, and equivalent widths are extremely sensitive to the assumed MLT parameterization. The authors find systematic uncertainties ranging from 25% for effective temperatures to 11% for mass and radius. The WET is engaged in a long term project to empirically determine the physical properties of convection in the atmospheres of pulsating white dwarfs. The technique, outlined by Montgomery et al. (2010), uses information from nonlinear (non-sinusoidal) pulse shapes of the target star to empirically probe the physical properties of its convection zone. Approximately two thirds of all white dwarfs show nonlinear characteristics in their light curves. We present current results from WET targets in 2008-2011.

439.15 – **Eclipse Mapping of HAT-P-11: Measuring Small Scale Starspots on an Active K-Dwarf**

Woody Austin[1], L. Hebb[1], K. Stassun[1]

[1]Vanderbilt University.
9:00 AM - 2:00 PM

With the continuing operation of the Kepler and CoRoT satellites, high precision space-based photometry is now available for a large number of transiting planet host stars. Using short cadence light curves with photometric precision of better than 10^{-4}, we are now, for the first time, able to map relative brightness variations due to small-scale starspots on the surfaces of many stars other than the Sun. We have developed an eclipse mapping analysis code, which applies the Nelder-Mead Simplex (Amoeba) Algorithm to transiting planet host stars to derive relative surface brightness maps of these distant stars. We test our code on the K-dwarf planet host star, HAT-P-11, which shows small flux variations during the transit due to the planet crossing in front of a star spot. In this poster, we present initial results produced by our eclipse mapping code for this system using short cadence Kepler light curves from Quarters 1-4.

439.16 – **3D Kinematic Reconstruction of Cas A's High-Velocity Ejecta Jets**

Dan Milisavljevic[1], R. Fesen[2]

[1]*Harvard CfA,* [2]*Dartmouth College.*

9:00 AM - 2:00 PM

A three-dimensional kinematic reconstruction of the optical emission from the Galactic supernova remnant Cassiopeia A (Cas A) encompassing both the main shell and the NE and SW streams of high-velocity ejecta (aka 'jets') is presented. The 3D map has been created from radial velocities and relative emission line strengths extracted from over 10,000 spectra covering the wavelength region 4000-8000 Angstroms. Also presented are 2010 HST/WFC3 observations obtained with the F098M filter sensitive to [S III] 9069, 9531 and [S II] 10287-10370 emissions that reveal the extent of ejecta in never-seen-before depth. These observations permit investigation of the jets' nature and relation to the remnant's overall dynamics, which in turn can be used to draw inferences about how the original explosion took place. This new 3D reconnaissance of Cas A's highest velocity ejecta may serve as a useful guide for multi-dimensional CCSN models that incorporate explosion asymmetries and bipolar jets.

439.17 – **Chromium Abundance Determination Utilizing Ionization Equilibrium In Two Very Metal-poor Stars**

Matthew Alvarez[1], J. S. Sobeck[2], J. E. Lawler[3], E. A. Den Hartog[3], C. Sneden[1], J. J. Cowan[4]

[1]*University of Texas,* [2]*University of Chicago,* [3]*University of Wisconsin,* [4]*University of Oklahoma.*

9:00 AM - 2:00 PM

We derive the neutral (Cr I) and singly-ionized (Cr II) abundances of HD 84937 (main-sequence turnoff star) and HD 115444 (*n*-capture enhanced red giant) to investigate the abundance discrepancy between individual chromium species. High resolution stellar spectra were taken by the Hubble Space Telescope STIS, the Very Large Telescope UVES, and Keck I HIRES echelle spectrographs. Improved oscillator strengths are used to analyze the transitions of both chromium species over a wavelength range of 2300-5400A. The derived chromium abundance offset for each star is consistent with previous investigations in the literature.

439.18 – **EC04207-4748 and EC05221-4725: Preliminary Results from the Whole Earth Telescope Campaign XCOV28**

James Dalessio[1], J. L. Provencal[1], H. L. Shipman[1]

[1]*University of Delaware.*

9:00 AM - 2:00 PM

We present multisite photometry of the pulsating helium atmosphere white dwarfs EC04207-4748 and EC05221-4745. EC04207-4748 is a high amplitude hot pulsator, a potential candidate for measuring the neutrino production rate in a white dwarf. EC05221-4725 is cooler as demonstrated by its rich long period pulsation spectrum.

439.19 – **Determination Of Physical Dimensions Of Mu Cas : From Abundance Analysis To Radiation-hydrodynamics**

Bach Kiehunn[1], Y. Kim[1], W. Kang[2]

[1]*Yonsei University, Korea, Republic of,* [2]*Kyunghee University, Korea, Republic of.*

9:00 AM - 2:00 PM

Physical properties of μ Cas astrometric binary have been studied through spectroscopic observation, abundance analysis, evolutionary computation, asteroseismology and 3-D Radiation-Hydrodynamics (RHD). In spite of the well-defined parallax and astrometric orbit from *HIPPARCOS*, there has been a chronic mass ratio problem between components. Most of all, accurate evolutionary solution of μ Cas system are still uncertain. Recently, the optical interferometric observation of the *CHARA* array has detected the radius of the primary star. At first, in order to define physical dimensions accurately, chemical composition has been investigated with the high resolution spectroscopy of *BOES*. From our elemental analysis, we find that μ Cas is composed of α–enhanced chemical mix with respect to the scaled solar abundance. Considering our newly determined relative abundance, physical parameters for μ Cas were calibrated in the context of stellar evolutionary theory. Through a statistical minimization among theoretical model grids, a reliable main-sequence solution ($0.8\,M\odot$, $0.2\,M\odot$) with its age $\sim$ 10 Gyr was determined. In addition, the p–mode oscillation spectrum of the best fit is estimated. With a well-constrained stellar parameters of the primary star, the 3-D Large Eddy Simulation (LES) including radiative transfer has been computed. Computational domain extends $32 \times 2Mm$ which covers several granules and $10 \sim 14$ pressure scale heights with the resolution of 1022×200 grids. The ultimate goal of this study is to describe detailed physical processes through a complete modelling for stars.

439.20 – **Metallicity Distribution of the Galactic Halo from SDSS Photometry**

Deokkeun An[1], T. C. Beers[2], J. A. Johnson[3], M. H. Pinsonneault[3], Y. Lee[4], Z. Ivezic[5], M. Newby[6]

[1]*Ewha Womans University, Korea, Republic of,* [2]*Michigan State University/JINA /NOAO,* [3]*Ohio State University,* [4]*Michigan State University/JINA,* [5]*University of Washington,* [6]*Rensselaer Polytechnic Institute.*

9:00 AM - 2:00 PM

We describe the methodology required for the estimation of photometric metallicity from the SDSS *ugriz* passbands and present a preliminary metallicity distribution of the Galactic halo system. Stellar isochrones have been empirically calibrated against observations of several star clusters over a wide range of metal abundance, and the accuracy of photometric $T_{\rm eff}$ and [Fe/H] from these models has been confirmed using the Infrared Flux Method (IRFM) $T_{\rm eff}$ scale and [Fe/H] values from the SDSS spectroscopic pipeline (SSPP). Based on these models, we estimate distances and metallicities for individual main-sequence stars in the SDSS Stripe 82 region, and present a preliminary *in situ* metallicity distribution of the halo system. Comparisons with numerical models and correlations between kinematic and metallicity distributions are discussed.

439.21 – **Young Supernova Remnant Candidates in the Southern Hemisphere**

William Robbins[1], V. Moss[1], B. M. Gaensler[1], T. Murphy[1], A. J. Green[1]

[1]*Sydney Institute for Astronomy, School of Physics, The University of Sydney, Australia.*

9:00 AM - 2:00 PM

Studies of the youngest supernova remnants (SNRs) provide the tantalizing opportunity to probe the circumstellar environment of their progenitor; to study the details of the explosive process; and to examine the efficiency of cosmic ray acceleration by shocks. We present detailed radio observations of four SNR candidates which, based upon their angular scale, could be the youngest in the Galaxy. To provide a more complete picture of the nature of these sources and their environments, we will present our radio data along with multi-wavelength data from various surveys.

439.22 – **Evaluating Early-time vs. Late-time Chemical Evolutionary Tracers in Starless Cores**

Amy Robertson[1], Y. Shirley[1]

[1]*University of Arizona.*

9:00 AM - 2:00 PM

Starless cores are the earliest observable phase of star formation and represent the initial conditions of protostar and disk formation. Mapping observations of molecular species toward starless cores indicate that starless cores are dynamically evolving at different rates and that the chemical evolutionary history is encoded within the observed molecular distributions. The current generation of chemo-dynamical models make general predictions about the abundance variations of species with many molecules separated into ”early-time” (high abundances early in evolution) and ”late-time” species. In this poster, we test the viability of SO and NO as “early time” and “late time” species by comparing to observations of known “late time” and “early time” molecules (e.g. NH3, CCS, etc.).

439.23 – **Element Distributions In The Crab Nebula**

Gordon M. MacAlpine[1], A. Sibley[1], A. Katz[1], T. Satterfield[1], A. Uomoto[2]

[1]*Trinity Univ.,* [2]*Carnegie Observatories.*

9:00 AM - 2:00 PM

We have obtained images of the Crab Nebula through interference filters passing the emission of Hβ, HeI λ5876, HeII λ4686, [CI] λλ9823,9850, [NII] λλ6548,6583, [OI] λλ6300,6364, [SII] λλ6716,6731, [SIII] λ9069, [NiII] λ7378, and the synchrotron continuum. After we registered the images and adjusted their point spread functions to be identical, they were flux calibrated and continuum subtracted. Then each pixel was compared to the output line emission for a grid of approximately 20,000 photoionization models with nested abundance ranges. We will present the resultant abundance or mass-fraction distribution maps for the elements He, C, N, O, S, and Ni.

439.24 – **Mass-loss History of a 'typical' AGB Star, Mira, Using Far-Infrared Imaging Photometry**

Basil Menzi Mchunu[1], A. K. Speck[1]

[1]*Univ. of Missouri - Columbia.*

9:00 AM - 2:00 PM

During the Asymptotic giant branch (AGB) phase intermediate mass stars suffer mass loss which leads to the formation of a circumstellar shell of gas and dust. At the end of the AGB phase, a star develops a superwind that leads to the exhaustion of the outer stellar envelope. Then the star evolves off the AGB and becomes a pre-planetary nebula (PPN) for short time ~ 1000 years.

At this stage the mass loss has significantly decreased or stopped, and the circumstellar shell begins to drift away from the star. When the stellar core evolves to high enough effective temperatures to produce photo-ionizing radiation, the circumstellar dust shell gets ejected (to the interstellar medium) and the star becomes a planetary nebula (PN). If the velocity of the AGB wind has been relatively constant, then dust furthest from the star represents the oldest mass loss, while material closer to the star represents more

recent mass loss. Hence, the history of mass loss during the AGB phase is imprinted on the dust shells of AGB and post-AGB envelopes.

We present the results and analysis of linear map scans from far infrared image observations of prototypical AGB star Mira, that were taken using IRAS, ISOPHOT, Spitzer telescopes in order to determine a) the history of mass loss, and b) to measure the total mass of the circumstellar dust from which we can infer the lower limit to the initial mass of the progenitor star. Furthermore, we derived the profile of dust emission spectral index vs. dust temperature that is useful in the study of the distribution of matter within the shells. We discuss the nature of the dust shells in terms of the derived spectral energy distribution implied by the observations.

439.25 – **Chemical Abundances of CH Stars in Omega Centauri**

Elizabeth Otto[1], J. Johnson[1]

[1]*The Ohio State University.*
9:00 AM - 2:00 PM

Omega Centauri, the largest globular cluster in the galaxy, is an important environment for studying nucleosynthesis because of its significant abundance variations and evidence of multiple stellar generations. The cluster also contains several known CH stars, which are thought to be the result of past binary mass transfer from an asymptotic giant branch (AGB) companion. CH stars are thus hypothesized to be a good probe of AGB nucleosynthesis. We use the CH stars in Omega Centauri to test this assumption. We compare the elemental abundances of CH stars within the cluster to those of CH stars outside the cluster to test the effects of the formation environment on the abundances of AGB nucleosynthesis products. We also compare the chemical abundances of the Omega Cen CH stars to other red giants in the cluster to determine if the same processes are responsible for the chemical enrichment of both the CH stars and the cluster. In general, we find that the CH stars in Omega Cen have similar abundances to CH stars in the field. We also find that as metallicity increases, the s-process abundances of stars in Omega Cen approach those of the CH stars, indicating that similar mechanism are responsible for the enrichment in both cases.

439.26 – **The Red Giant Branch Bump as a Probe of Stellar Populations**

David Nataf[1]

[1]*The Ohio State University.*
9:00 AM - 2:00 PM

I show that the Galactic bulge red giant branch bump, never previously measured, is indicative of an old, helium-enhanced stellar population. The analysis is done by comparing to data: 72 Galactic globular clusters measured with the Hubble Space Telescope, and to the Yale Rotating Evolution Code. Additionally, a large age difference with the Galactic globular cluster system is ruled out.

439.27 – **HR7672B: A Benchmark Brown Dwarf with High Eccentricity**

Justin R. Crepp[1], J. A. Johnson[1], California Planet Search

[1]*California Institute of Technology.*
9:00 AM - 2:00 PM

We present the first three-dimensional orbit and dynamical mass determination of the L4-dwarf HR7672B. Our observations, which include more than 24 years of precise Doppler measurements and 10 years

of direct imaging astrometry, firmly establish this companion as a substellar object with a high (~0.5)

eccentricity. Conveniently orbiting a G0V star, HR7672B is presently the only brown dwarf with a known mass, age, metallicity, and luminosity, and therefore represents an ideal laboratory for testing theoretical evolutionary models and synthetic spectral models.

439.28 – **Searching for Binary Systems in Planetary Nebulae Using the ISIS Image Subtraction Software**

Samantha Jo Schwartz[1], T. Hillwig[1]

[1]*Valparaiso University.*
9:00 AM - 2:00 PM

We are exploring the theory that binary central stars of planetary nebulae are a contributing factor in the formation of planetary nebulae. Since periodic variability is indicative of a close binary system, we search for photometric variability in the central stars of planetary nebulae. The variability of our targets is assessed with the image subtraction software, ISIS. We find that the central stars of the planetary nebulae Hen 2-84 and NGC 6326 show variability. A preliminary light curve for Hen 2-84 shows periodic behavior, suggesting a binary system. We do not have sufficient data for NGC 6326 to determine periodicity, but our results are consistent with previous work that does show periodic behavior. Of the remaining targets observed, with sufficient data, seven do not appear to have substantial variability detected through ISIS and two targets have undeterminable variability.

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440 – Cosmology and Related Topics

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

440.01 – **The BigBOSS Multi-Object Spectrograph on the Mayall Telescope: Guide, Focus and Alignment Sensor System**

Kevin Reil[1], BigBOSS Collaboration

[1]*SLAC National Accelerator Lab.*
9:00 AM - 2:00 PM

The BigBOSS experiment is proposed as a Stage IV dark energy survey. By measuring the spectroscopic redshift of 20 million galaxies baryon acoustic oscillation (BAO) effects in the local universe will be measured. The instrument will consist of 5000, remotely actuated optical fibers that transport light from the focal plane to a collection of spectrographs. For every exposure all 5000 fibers will moved to the focal location of a target within their range, typically a luminous red galaxy (z<1.0) or bright emmision line galaxy (z<1.7).

The combination of 120 micron (1.44") diameter fibers with 0.8" seeing and many optical and mechanical tolerances leaves little margin in preventing loss of light. BIGBOSS is therefore required to not only hold the telescope steady on the same sky location but also to orient the telescope and fibers so that pointing is *absolutely* correct on the sky. This will require excellent stellar astrometry for guiding, precise galactic astrometry, accurate fiber positioning, pinpoint focus, detailed pointing determination, and smooth tracking by the almost 40 year old telescope.

A preliminary design of the focus and alignment system for BigBOSS will be presented.

440.02 – **Measuring the Power Spectrum with Peculiar Velocities**

Edward Macaulay[1], H. A. Feldman[2], P. G. Ferreira[1], A. H. Jaffe[3], S. Agarwal[2], M. J. Hudson[4], R. Watkins[5]

[1]*University of Oxford, United Kingdom,* [2]*University of Kansas,* [3]*Imperial College, London, United Kingdom,* [4]*University of Waterloo, Canada,* [5]*Willamette University.*
9:00 AM - 2:00 PM

The peculiar velocities of galaxies are an inherently valuable cosmological probe, providing an unbiased estimate of the distribution of matter on scales much larger than the depth of the survey. Much research interest has been motivated by the high dipole moment of our local peculiar velocity field, which suggests a large scale excess in the matter power spectrum, and can appear to be in some tension with the LCDM model.

We use a composite catalogue of 4,537 peculiar velocity measurements with a characteristic depth of 33 h-1 Mpc to estimate the matter power spectrum. We compare the constraints with this method, directly studying the full peculiar velocity catalogue, to results from Macaulay et al. (2011), studying minimum variance moments of the velocity field, as calculated by Watkins, Feldman & Hudson (2009) and Feldman, Watkins & Hudson (2010). We find good agreement with the LCDM model on scales of k > 0.01 h Mpc-1. We find an excess of power on scales of k < 0.01 h Mpc-1, although with a 1 sigma uncertainty which includes the LCDM model. We find that the uncertainty in the excess at these scales is larger than an alternative result studying only moments of the velocity field, which is due to the minimum variance weights used to calculate the moments. At small scales, we are able to clearly discriminate between linear and nonlinear clustering in simulated peculiar velocity catalogues, and find some evidence (although less clear) for linear clustering in the real peculiar velocity data.

440.03 – **Title: Measuring Luminosity Dependent Quasar Clustering**

Jessica Kirkpatrick[1]

[1]*Lawrence Berkeley National Lab.*
9:00 AM - 2:00 PM

Whether luminous quasars reside in dark matter halos of the same mass and accrete at different rates, or, live in haloes of different masses, and accretion is near the Eddington limit, is still an open question. Here, we present measurements of the luminosity-dependence of quasar clustering, using data from the SDSS, 2SLAQ QSO and the new SDSS-III: BOSS Quasar surveys, allowing us to span ~4 magnitudes in luminosity, at a given redshift. Using a cross-correlation technique, we measure the clustering of ~3100 0.5<z<1.0 spectroscopic quasars with 5.4million photometric galaxies brighter than *i*-band = 23.75, selected from the CFHT survey on Stripe-82 (CS82). We find a strong detection of clustering in the cross-correlation and will discuss the amplitude of the clustering, as a function of redshift, luminosity, black-hole mass and Eddington ratio of the quasar sample.

440.04 – **A Cosmic Shear Measurement from SDSS**

Eric M. Huff[1], T. Eifler[2], C. M. Hirata[3], R. Mandelbaum[4], D. Schlegel[5], U. Seljak[6]

[1]*UC Berkeley,* [2]*Center for Cosmology and AstroParticle Physics, The Ohio State University,* [3]*Caltech,* [4]*Department of Astrophysical Sciences, Princeton University,*

[5]*Lawrence Berkeley National Laboratory,* [6]*Department of Astronomy, Department of Physics, UC Berkeley.*
9:00 AM - 2:00 PM

Weak lensing by large-scale structure is an invaluable cosmological tool in the era where most of the energy density of the concordance cosmology is invisible. Several large ground-based imaging surveys will attempt to measure this effect over the coming decade, but reliable control of the major systematic effects arising from atmospheric turbulence and telescope optics, shear miscalibration, intrinsic galaxy alignments, and photometric redshift inference remains a challenging problem.

We present a cosmic shear measurement using Sloan Digital Sky Survey imaging that addresses each of these challenges. We describe our procedure for lensing-optimized image coaddition, the results of careful modeling of each of the systematic errors, and the constraints our analysis puts on the concordance cosmology.

440.05 – **Cosmological Constraints from Cosmic Shear in CFHTLenS**

Martin Kilbinger[1], CFHTLenS Collaboration (www.cfhtlens.org)

[1]*CEA, France.*
9:00 AM - 2:00 PM

We present constraints on cosmological parameters from weak gravitational lensing by the large-scale structure. Using multi-band optical data over 155 square degrees of the CFHTLenS survey, we measure the shear correlation out to very large, linear scales. We calculate the covariance of the data from N-body and ray-tracing simulations. We sample the parameter space using Population Monte Carlo (PMC), and obtain robust constraints on LCDM and dark-energy models. We estimate the Bayesian evidence which allow us to compare different cosmological models.

440.06 – **Fundamental Physics With Large-scale Structure: Modified Gravity, Non-Gaussianity, And Gravity Waves**

Fabian Schmidt[1]

[1]*California Institute of Technology.*
9:00 AM - 2:00 PM

Testing our theory of gravity, and probing the initial conditions of the Universe are two of the main goals of cosmology. I will show that large-scale structure is uniquely suited to do the former, and can add valuable information to CMB measurements for the latter. In particular, I will present current and upcoming constraints on modified gravity models from large-scale structure which take into account the non-linear screening mechanism present in these models. Further, I will show how the large-scale clustering of galaxies can serve as a unique probe of primordial non-Gaussianity, providing constraints complementary to the CMB. Finally, I will show how we can search for primordial gravity waves using the observed distribution of galaxies.

440.07 – **Cfhtlens: Third-order Galaxy-galaxy Lensing As Function Of Stellar Mass, Luminosity And Galaxy Type**

Patrick Simon[1]

[1]*Argenlander-Institut Fuer Astronomie, Germany.*
9:00 AM - 2:00 PM

Third-order galaxy-galaxy lensing (G3L) or galaxy-galaxy-galaxy lensing is the next generation galaxy-galaxy lensing (GGL) in the field of weak gravitational lensing. In contrast to the traditional GGL -- successfully employed to determine the average radial matter density profile about lens galaxies -- G3L is a three point correlation function that involves either two lenses and one background source or two sources and one lens. The former quantifies the average excess matter about physically close lens pairs, i.e., in excess of the expected lensing signal if all lenses were isolated and scattered without clustering. The latter expresses the lens-to-lens variance of the shear pattern exerted by matter associated with individual lenses. The GFHTLenS allows us for the first time to measure G3L for lenses with varying properties such as luminosity, stellar mass or redshift. In our empirical study, a significant change of the both lensing signals with luminosity ($-23<M_r/mag<-18$) and stellar mass ($0.5<h^2$ Mstar/1E10<6.4) is found, while a convincing change with lens redshift from z~0.3 to z~0.5 is not observed. Both G3L correlation functions exhibit a stronger signal for more luminous (up to factor 4) or stellar mass richer (up to factor 7) lenses. This is accompanied by a faster decline of the excess mass signal towards larger angular scales for more luminous or stellar mass rich lenses. Luminous ($M_r<-21$ mag) late-type galaxies display no detectable excess mass. All excess mass detected for luminous galaxies seems to be associated with early type galaxies. Our conclusions factor in a novel correction for the anticipated change in the G3L signal due to differing radial distance distributions of lenses or sources.

440.08 – **A Murchison Widefield Array 32-Tile Survey of EoR Foregrounds**

Christopher L. Williams[1], J. N. Hewitt[1], Murchison Widefield Array Collaboration

[1]*MIT.*
9:00 AM - 2:00 PM

The Murchison Widefield Array (MWA) is a new low-frequency, wide field-of-view radio array under construction in Western Australia, with a goal of detecting and characterizing radio emission from the epoch of reionization (EoR). We have used a 32-element MWA prototype interferometer to observe a candidate field for our epoch of reionization experiment across the 110MHz to 200MHz frequency band. In less than 6 hours of integration we produce confusion limited maps of our field covering more than 600 square degrees over a 30.72 MHz instantaneous bandwidth, demonstrating the MWA's performance as a survey instrument. The population of sources detected in these observations serves as a first step towards identifying and characterizing the foregrounds which will need to be subtracted in order to measure the EoR signal. We present the results of our survey and use additional low-frequency catalogs to identify several ultra-steep spectrum radio source candidates in our sample.

440.09 – **The Hunt for the First Supernovae: The Source Density and Observability of Pair Instability Supernovae from the First Stars**

Jacob Hummel[1], A. Pawlik[1], M. Milosavljevic[1], V. Bromm[1]

[1]*The University of Texas at Austin.*
9:00 AM - 2:00 PM

Theoretical models predict the supernova explosions ending the lives of some of the first stars to have been extremely energetic Pair Instability Supernovae (PISNe). With energies approaching 10^{53} ergs, these supernovae are expected to be within the detection limits of the upcoming James Webb Space Telescope (JWST), allowing observational constraints to be placed on the properties of the first stars. We calculate the source density of PISNe using a semi-analytic model informed by cosmological simulations including molecular cooling and radiative feedback. The inclusion of feedback reduces the source density significantly, suggesting that a mosaic search strategy may be the best approach.

440.10 – **Dynamics of Dust in Plasma and Implications to CMB and Magnetic Fields Studies**

Thiem Hoang[1]

[1]*Univ. Of Wisconsin-Madison.*
9:00 AM - 2:00 PM

Dust is a ubiquitous constituent of the interstellar medium, molecular clouds, and circumstellar and protoplanetary disks. Dust emission interferes with observations of cosmic microwave background (CMB) temperature anisotropy and its polarized emission dominates the CMB B-mode polarization that prevents us from getting insight into the inflation epoch of the early universe. We study fundamental physical processes of dust dynamics in plasma and explore their implications to observations of the CMB, studies of magnetic fields, and formation of planets. We quantified spinning dust emission (SDE) from wobbling small grains with non-spherical shapes. We investigated the effects of transient heating by UV photon and compressible turbulence on SDE. This improved SDE model reproduces very well observation data by Wilkinson Microwave Anisotropy Probe and allows a reliable subtraction of Galactic contamination from the CMB. We identified grain helicity as the major driver for grain alignment via radiative torques (RATs) and suggested an analytical model of RATs based on this concept. Dust polarization predicted by the model has been confirmed by numerous observations, and can be used as a frequency template for the CMB B-mode searches. We proposed a new type of dust acceleration due to magnetohydrodynamic turbulence through transit time damping for large grains and quantified a novel acceleration mechanism induced by charge fluctuations for very small grains using Monte Carlo simulations. Grain velocities from these new acceleration mechanisms are necessary for understanding dust coagulation in protoplanetary disks and formations of planets.

440.11 – **Cosmic Microwave Background Fluctuations from the Kinetic Sunyaev-Zeldovich Effect as a Cosmological Probe**

Hyunbae Park[1], P. Shapiro[1], E. Komatsu[1]

[1]*The University of Texas at Austin.*
9:00 AM - 2:00 PM

We present a calculation of the kinetic Sunyaev-Zel'dovich (kSZ) effect on of the Comic Microwave Background fluctuation. We focus on the scale at the multipole moment of l = 3000 ~ 10000 that is currently being probed by the South Pole Telescope (SPT) and the Atacama Cosmology Telescope. For the post-reionization contribution of the total signal, we use the 3rd order perturbation theory (3PT) to model non-linearity of post-reionization epoch. We evaluate a non-linear expression for momentum powerspectrum in Ma and Fry (2002) with the 3PT density and velocity powerspectrum. And, we use the 3PT momentum powerspectrum to calculate the kSZ signal. We show that the 3PT is a reasonable approximation by comparing our result with previous work by Zhang, Pen and Trac (2004). For reionization contribution, we use our N-body radiative transfer simulations to take patchiness of ionization of intergalactic medium in reionization epoch into account. Using ionized fraction field in the simulation, we calculate the momentum field of the ionized gas. And, we correct for the missing power in finite size boxes of simulations. Finally, we show the kSZ calculation for different simulations with reionization scenarios. With contributions from each epoch, we predict total kSZ signal for different reionization history and put constraint on reionization scenario using an upper bound of the signal from recent SPT measurement.

440.13 – **A New Method of Detecting Primordial Black Hole Dark Matter using Microlensing**

Agnieszka Cieplak[1], K. Griest[1], M. J. Lehner[2]

[1]*University of California, San Diego,* [2]*University of Pennsylvania.*
9:00 AM - 2:00 PM

Primordial Black Holes (PBHs) are the only remaining Dark Matter (DM) candidate of the Standard Model of Particle Physics. We present a new method of constraining up to 40% of the remaining mass range of the PBH DM using microlensing of stars targeted by NASA's Kepler mission. Kepler's exceptional photometric precision and finite-source effects allow for a higher microlensing rate than previously thought. We introduce a new formalism with these effects for the optical depth and microlensing rate.

440.14 – **Identifying Compact Binary Mergers Using Gravitational Wave Measurements And Electromagnetic Wide-field Surveys**

Samaya Nissanke[1]

[1]*Caltech/JPL.*
9:00 AM - 2:00 PM

The strongest gravitational waves in the universe are attributed to the mergers of neutron star or black hole binaries. Decades of theoretical and experimental efforts are about to culminate perhaps within this decade in the first direct detection of gravitational waves. These resulting measurements will offer us an unprecedented view of strong-field astrophysics in action. This talk discusses our ongoing effort aimed at preparing astrophysical follow-up studies of the gravitational-wave source. This effort is critical in improving our understanding of the source's physical properties. In particular, as a first and essential step, I will outline the challenges that lie ahead and present our solution in how to pinpoint the location of compact binary mergers using networks of gravitational-wave interferometers and electromagnetic synoptic wide-field surveys.

440.15 – **Evidence For Spin In Compact Binary Coalescence: When Can We Trust It ?**

Vivien Raymond[1]

[1]*Northwestern University.*
9:00 AM - 2:00 PM

LIGO/Virgo will soon enter their advanced phases and, among the anticipated detections, compact binary coalescences are of special interest because these events are the most promising for extracting to extract astrophysical parameters of source systems. In order to do so, spin effects in the parameter estimation analysis have to be included. Given the complexity inherent to the high dimensions and strong correlations of the spinning parameter space, one can ask what limits our ability to distinguish non-spinning versus spinning signals. One way to answer this question is to explore when a non-spinning signal becomes indistinguishable from a spinning signal.

We use our Bayesian inference code to compute evidences for non-spinning and spinning models on various injections, and try to assess the location in parameter space where non-spinning signals can hide.

440.16 – **Re-Purposed MCMC for Low-Latency Sky Localization of Gravitational Wave Sources**

Benjamin F. Farr[1], V. Raymond[1], W. M. Farr[1], D. Fazi[1], J. Veitch[2], I. Mandel[3], B. Aylott[3], C. Röver[4], V. Kalogera[1]

[1]*Northwestern University,* [2]*Cardiff University, United Kingdom,* [3]*University of Birmingham, United Kingdom,* [4]*Albert-Einstein-Institut, Germany.*
9:00 AM - 2:00 PM

The electromagnetic followup of a gravitational wave event would not only increase confidence in the first detection, but also allow us to extract substantially more astrophysical information from the source. In order to promptly follow up a gravitational wave trigger, its sky position must be inferred as quickly and accurately as possible from the gravitational wave signature. For compact binary sources, low-latency sky localization is currently done using incoherent methods. These methods, though capable of producing results in seconds, have large uncertainties. We have re-purposed our Markov-Chain Monte Carlo parameter estimation code, originally designed for coherent searches over the 15 dimensional parameter space of a circularized compact binary merger, for low-latency sky localization. We anticipate that MCMC techniques will better estimate confidence regions, but do so with a runtime of hours. We show that through the use of specialized jump proposals and algorithm optimizations, runtime to achieve comparable sky maps can be reduced to minutes.

440.17 – **The Influence Of General Relativity On The Stability Of Orbits Far From Galaxies**

Jerry Schirmer[1]

[1]*University of Texas at Austin.*
9:00 AM - 2:00 PM

Given a central black hole and a cosmological constant, it is found that orbits generically have innermost and outermost stable circular orbits. The location of outermost orbits is explored for a variety of exact cosmological solutions, and its location is shown to be of a similar order of magnitude to observed galaxies when the accepted values for cosmological constants and galactic masses are used.

440.18 – **A Generic Stochastic Template Bank Placement Algorithm**

Melissa Frei[1], N. Fotopoulos[2], S. Priviteria[2]

[1]*RIT,* [2]*Caltech.*
9:00 AM - 2:00 PM

Black hole binary (BBH) systems represent strong candidates for gravitational wave (GW) detection by GW detectors LIGO and Virgo. BBH searches are template based searches where the templates describe potential GWs. Most BBH sources are spinning strongly enough to affect orbital dynamics though past searches have all been for non-spinning systems. Neglecting spin results in a significant decrease in a BBH search's sensitivity to spinning systems while the inclusion of leading order, single parameter spin corrections regain much of that sensitivity. BBH templates in past searches were chosen so that the overlap between neighboring templates was 97%. The optimal placement of non-spinning, inspiral templates is known but does not work for systems described by more parameters. For spinning systems, the placement metric is not known and stochastic methods like the one described in this poster are necessary. The method described here is based on previous stochastic work. It represents a fast, flexible, open-source tool using publicly available LIGO Algorithms Library (LAL) to generate stochastic banks for any template family no matter the number of parameters used to describe it. The method shows more efficient coverage of the parameter space of interest than a discrete stacking of a two-dimensional bank in a third direction.

440.19 – **Galaxy Evolution at the Cluster- Filament Interface of SuperGroup Abell 1882**

Aparajita Sengupta[1], W. Keel[1], G. Morrison[2]

[1]*University of Alabama,* [2]*Canada-France-Hawaii Telescope (CFHT) Corp..*
9:00 AM - 2:00 PM

Super Groups (SG) facilitate our understanding of filament-cluster core interaction at a different dynamical scale as compared to a more evolved and relaxed system like the Coma Cluster. We study 279 spectroscopically confirmed members of a highly filamentary-type SG, Abell 1882 (redshift ≈ 0.1365), which is composed of groups caught just before coalescing into a rich cluster.

We have probed the effects of environment on Star Formation Rate and Star Formation History of the member galaxies for the first time, using multi-band data from SDSS, GALEX and SPITZER, as they are first pre-processed in the filaments in the super-cluster environment, then in the intermediate region where galaxies make a transition from filament environment to Super Group environment, and finally in the deeper, denser recesses of Super Group potential of Abell 1882.

From the preliminary study, there is an indication that the star-forming dwarf galaxies (Mass(star) < 10^{10} Mass(sun) and with 24 micron emission) exhibit a higher level of clumpiness as they approach the high density group environment. This strongly indicates enhanced star formation and disturbed morphology due to mergers/interactions at least for the shallower potentials.We also detect an over-density of red galaxies in the apparent filaments which are at the high density region of the Super Group.

SGs are rare at low redshifts, and coupled with its poor X-Ray emitting atmosphere, Abell 1882 offers us a very efficient system to study the individual galaxies and their evolution within the ICM.

440.20 – **Using Quasars as Standard Candles for Studying Dark Energy**

Kelly D. Denney[1], M. Vestergaard[1], D. Watson[1], T. Davis[2]

[1]*Dark Cosmology Centre, Niels Bohr Institute, Denmark,* [2]*University of Queensland, Australia.*
9:00 AM - 2:00 PM

We have recently demonstrated (Watson et al. 2011, ApJ, 740, L49) that quasars, or more generally active galactic nuclei (AGNs), can be used as standard candles for measuring distances in the universe, similar to Type Ia supernovae (SNe). Here, we present the initial findings of this new method, which relies on the technique of reverberation mapping to measure time delays between the quasar continuum and emission line variability signatures. Measuring this time delay effectively measures the radius between the central source and the emission-line gas. The emission line gas is photo-ionized by the continuum photons, and the radius to this emission-line region scales tightly with the nuclear luminosity - a consequence of the photoionization physics responsible for regulating the production of line-emitting photons. Hence, measuring the radius of the emission-line gas provides a measure of the intrinsic luminosity of the AGN, allowing for the determination of the AGN distance. Since AGNs are luminous and the emission line spectrum is easily visible at high redshifts (e.g., out to z~4), AGN-based distances can be used to extend the distance ladder past the SNe cutoff (z~1.5). This regime is where the power to distinguish the possible time dependence of the dark energy equation of state lies. We present our initial discovery AGN Hubble diagram of nearby reverberation mapped sources and discuss ways (1) to extend this in redshift and (2) to reduce the current scatter. We also present simulated forecasts

demonstrating the power this method can have over, e.g., SNe, to constrain dark energy parameters by extending to higher redshifts than can currently be probed with any other technique.

441 – Did Someone Say Galaxies?

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

441.01 – **Disentangling Correlated Scatter In Cluster Mass Measurements**

Yookyung Noh[1], J. D. Cohn[1]

[1]*University of California Berkeley.*

9:00 AM - 2:00 PM

Galaxy cluster masses are of interest for many areas of astrophysics and cosmology. Multi-wavelength observations of clusters are now underway to better constrain masses both for individual clusters and ensembles of clusters. However, many of these cluster mass measurements have been found to have correlated scatter, which can lead to measurement errors and/or bias if not accounted for. We consider mock observational mass measurements of galaxy clusters in a high resolution N-body simulation to better understand how scatters of different mass measurements are related to each other and how physical and observational properties of galaxy clusters are connected to these scatters. By observing each cluster from ~96 different directions, we find the range of scatters for each observational method and use principal component analysis (PCA) to identify the combinations of mass measurements which maximize and minimize these mass scatters. We then find the correlation of these scatters with the physical cluster or environmental properties. We also consider the ensemble of clusters, and discuss outliers and what physical and observational properties might distinguish them.

441.02 – **Kinematics of the Diffuse Ionized Gas Disk of Andromeda**

Alexander Thelen[1], K. Howley[2], P. Guhathakurta[1], C. Dorman[1], SPLASH Collaboration

[1]*University of California, Santa Cruz,* [2]*Lawrence Livermore National Laboratory.*

9:00 AM - 2:00 PM

This research focuses on the flattened rotating diffuse ionized gas (DIG) disk of the Andromeda Galaxy (M31). For this we use spectra from 25 multislit masks obtained by the SPLASH collaboration using the DEIMOS spectrograph on the Keck-II 10-meter telescope. Each mask contains ~200 slits covering the region around M32 (S of the center of M31), the major axis of M31, and the SE minor axis. DIG emission was serendipitously detected in the background sky of these slits. By creating a normalized "sky spectrum" to remove various other sources of emission (such as night sky lines) in the background of these slits, we have examined the rotation of the DIG disk using individual line-of-sight velocity measurements of Hα, [NII] and [SII] emission. This emission is probably the result of newly formed stars ionizing the gas in the disk. The measured DIG rotation will be compared to the rotation of M31's stellar disk and HI gas disk, as well as models of an infinitely thin rotating disk, to better understand the relationship between the components of the galactic disk and its differential rotation.

We wish to acknowledge the NSF for funding on this project.

441.03 – **Average Heating Rate of Hot Atmospheres in Distant Clusters by Radio AGN**

Cheng-Jiun Ma[1], B. McNamara[2], P. Nulsen[1]

[1]*SAO,* [2]*University of Waterloo, Canada.*

9:00 AM - 2:00 PM

AGN feedback is long believed to be an essential ingredient of cosmic structure formation to provide the extra energy required to slow the rapid acquisition of materials. In galaxy clusters, the quasar mode of AGN were interpreted as a possible candidate of energy source in the preheating model which suggests that the excess energy is injected at early universe. The radio mode of AGN, on the other hand, were thought to be less powerful, and only be fairly enough to balance the radiation loss of cooling core clusters. In this work, we examine atmospheric heating by radio AGN in distant X-ray clusters by cross correlating clusters selected from a composition of eight X-ray cluster surveys with radio sources in the NRAO VLA Sky Survey. The AGN heating for each radio source is determined using scaling relations between radio power and cavity (mechanical) power determined for nearby clusters, groups, and galaxies with hot atmospheres containing X-ray cavities. We find that the continuous heating from the radio AGN could reach more than 1keV per particle in the less massive clusters. This suggests that the contribution of the radio mode AGN is undervalued. In fact, the radio AGN alone could provide enough energy/entropy to explain the deviation of the scaling relations expected from self-similarity, and the preheating may not be necessary.

441.04 – **The Eating Habits of Giants and Dwarfs: Chemo-dynamics of Halo Assembly in Nearby Galaxies**

Aaron J. Romanowsky[1], SAGES team

[1]*University of California Observatories.*

9:00 AM - 2:00 PM

I will present novel results on the halo assembly of nearby galaxies, from dwarfs to the most massive ellipticals, using Subaru imaging and Keck spectroscopy. Field stars, globular clusters, and planetary nebulae are used as wide-field chemo-dynamical tracers, mapping out halo substructures that were previously known and unknown. Comparisons are made with simulations of galaxy formation.

Supported by the National Science Foundation Grants AST-0808099, AST-0909237, and AST-1109878.

441.05 – **Galactic Disk Abundance Gradients and the 10 kpc R_g Region**

Jackie Milingo[1], R. B. C. Henry[2], K. B. Kwitter[3], B. Balick[4]

[1]*Gettysburg College,* [2]*University of Oklahoma,* [3]*Williams College,* [4]*University of Washington.*

9:00 AM - 2:00 PM

We examine the radial abundance gradient in the Milky Way disk via homogeneously determined data for 124 Galactic planetary nebulae. With O, Ne, S, Cl, and Ar available and a range of galactocentric distance (R_g) from 0.9 to 21 kpc, we explore the gradient by statistically analyzing a series of short segments of increasing average R_g. Though the detailed nature of the radial gradient remains somewhat uncertain, we find the short segments support a discontinuity at R_g ~10 kpc, consistent with that shown via open clusters, hence providing a potential constraint on the dynamic history of the Galactic disk.

441.06 – **Zpectrometer Blind Redshift Determinations for Distant Dusty Galaxies from the H-ATLAS Sample**

Andrew J. Baker[1], A. I. Harris[2], D. T. Frayer[3], I. Smail[4], M. Swinbank[5], H-ATLAS Team

[1]*Rutgers, the State University of NJ,* [2]*University of Maryland,* [3]*National Radio Astronomy Observatory,* [4]*Durham University, United Kingdom,* [5]*Durham Uinversity, United Kingdom.*

9:00 AM - 2:00 PM

Far-infrared imaging of wide fields through the *Herschel* Astrophysical Terahertz Large Area Survey (H-ATLAS) has revealed the existence of a population of very bright dusty galaxies, the majority of which are expected to be distant and gravitationally lensed. High obscuration in such systems can impede determination of their redshifts with optical spectroscopy. We are therefore pursuing these targets with radio-wavelength spectroscopy of CO rotational emission lines using the ultra-wide-bandwidth "Zpectrometer" on the 100m diameter Green Bank Telescope (GBT) of the National Radio Astronomy Observatory (NRAO). We have now obtained blind CO(1-0) redshifts of over a dozen objects from the H-ATLAS sample in the $2.1 < z < 3.5$ interval, allowing us to determine a redshift distribution over this range independent of optical spectroscopy systematics. With CO redshifts, fluxes, and velocity widths in hand, we can make comparisons with the properties of classical submillimeter galaxies (SMGs), leading us to infer similar intrinsic properties but moderate lensing factors for the *Herschel* sources.

441.07 – **Early Results from the VENGA Integral Field Spectroscopy Survey: Current and Past Spatially-Resolved Star Formation in NGC2903**

Mimi Song[1], K. Gebhardt[1], S. Jogee[1], VENGA

[1]*University of Texas at Austin.*

9:00 AM - 2:00 PM

We present spatially-resolved integral field spectroscopy of the nearby isolated spiral galaxy NGC 2903 from the VIRUS-P Exploration of Nearby Spiral Galaxies (VENGA) survey. Among science goals that the survey aims at, here we focus on its star formation activity, stellar population modeling and constraining its star formation history.

We acknowledge support from the Norman Hackerman Advanced Research Program (NHARP) ARP-03658-0234-2009.

441.08 – **AEGIS: The Morphologies of Green Galaxies at z~0.7**

Alexander Mendez[1]

[1]*UCSD.*

9:00 AM - 2:00 PM

We present quantitative morphologies of ~300 galaxies in the optically defined green valley at $0.4 < z < 1.2$, in order to constrain the mechanism(s) responsible for quenching star formation in the bulk of this population. The sample is selected from galaxies in the All-Wavelength Extended Groth Strip International Survey (AEGIS). While the green valley is defined using optical U - B colors, we find that using a green valley sample defined using NUV - R colors does not change the results. Using Hubble Space Telescope/Advanced Camera for Surveys imaging, we study several quantitative morphological parameters including CAS, B/T from GIM2D, and Gini/M20. We find that

the green galaxy population is intermediate between the red and blue galaxy populations in terms of concentration, asymmetry, and morphological type and merger fraction estimated using Gini/M20. We find that most green galaxies are not classified as mergers; in fact, the merger fraction in the green valley is lower than in the blue cloud. We show that at a given stellar mass, green galaxies have higher concentration values than blue galaxies and lower concentration values than red galaxies. Additionally, we find that 12% of green galaxies have B/T = 0 and 21% have B/T <= 0.05. Our results show that green galaxies are generally massive (M * ~ $10^{10.5}$ Msun) disk galaxies with high concentrations. We conclude that major mergers are likely not the sole mechanism responsible for quenching star formation in this population and that either other external processes or internal secular processes play an important role both in driving gas toward the center of these galaxies and in quenching star formation.

441.09 – **Feathering Instability of Spiral Arms and OB Star Formation**

Wing-Kit Lee[1], F. H. Shu[1]

[1]*University of California, San Diego.*
9:00 AM - 2:00 PM

Quasi-regular substructures of the spiral arm are commonly found in spiral galaxies. These substructures are known as feathers or spurs, and they jut out perpendicularly into the inter-arm region. They also associate with the Giant Molecular Clouds where massive star formation occurs. The formation of these density fluctuation can be studied from the perspective of perturbation of galactic spiral shock. We investigate the gas response under the influcence of the shock perturbation, and formulate the MHD equations in a local two-dimensional quasi-rectangular region between tightly-winding spiral arms. Our theoretical model includes the effect of magnetic field and self-gravity of the gas, we are are able to reproduce feather-like structures in the post-shock region. In this semi-analytical framework, the periodic density fluctuations depends on the various background parameters such as pattern speed, strength of spiral arm, surface density of the gas and strength of magnetic field. Potentially this study can help understand the inter-arm environment that will be observed in the nearby galaxies using submillimeter telescope such ALMA in the coming years.

441.10 – **The First Galaxies: Assembly and Radiative Feedback from the First Stars**

Andreas Pawlik[1], V. Bromm[1], M. Milosavljevic[1]

[1]*University of Texas Austin.*
9:00 AM - 2:00 PM

The James Webb Space Telescope (JWST) will soon enable us to probe galaxy formation at unexplored early times. Previous work has shown that the very first galaxies, i.e., galaxies inside halos with virial temperatures 10^4 K and masses ~ 10^8 solar at redshifts z > 10, are generally too faint, by at least one order of magnitude, to be detected even in very deep exposures with JWST. The light collected with JWST will therefore be dominated by radiation from galaxies inside ten times more massive halos. We use cosmological zoomed smoothed particle hydrodynamics simulations to investigate the formation of galaxies inside such halos. An intriguing outcome of our simulations is the assembly of rotationally supported galactic gaseous disks. We address the impact of star formation on the disk assembly by solving the hydrodynamically coupled transport of ionizing radiation from internal and external ionizing sources. We discuss the prospects for observations of galaxies such as simulated here with the JWST. This research is supported by NASA through Astrophysics Theory and Fundamental Physics Program grants NNX08AL43G and NNX09AJ33G and through NSF grants AST-0708795 and AST-1009928. The simulations presented here were carried out at the Texas Advanced Computing Center (TACC).

441.11 – **Cluster Mergers Induce Faint Galaxy Deficit In Luminosity Functions**

Kiyun Yun[1], S. Ahn[1], J. Kim[2], S. Kim[3], S. Yoon[1]

[1]*Yonsei Univ., Korea, Republic of,* [2]*Korea Institute for Advanced Study, Korea, Republic of,* [3]*Kyung Hee Univ., Korea, Republic of.*
9:00 AM - 2:00 PM

Recent surveys revealed curious deficit of faint galaxies (Mv > -18) in the luminosity functions (LFs) of cluster galaxies, compared to the LFs of field counterparts. Based on cosmological N-body simulations and a new GPU-based halo-finding scheme, we here present an explanation for the discrepancy in LFs of galaxies belonging to dense and rarified environments. In particular, we show that dynamical interactions among clusters of galaxies have (*a*) accelerated preferentially less-massive galaxies and (*b*) thus forced the low-mass galaxies to escape from the host cluster's potential well, leaving the faint deficit in the LFs. Many of the escaped galaxies become part of field environments for as long as a few Gyrs. In light of the scenario, we discuss the cause of the observed similarities between cluster and field galaxies in terms of stellar populations (e.g., star formation rate) and dynamics (e.g., the disk warp phenomenon).

441.12 – **Low Surface Brightness Galaxies and The AGN Connection: New Insights from the SDSS Survey**

Gaspar Galaz[1], R. Herrera[2], D. Garcia-Lambas[3], N. Padilla[1]

[1]*Pontificia Universidad Catolica de Chile, Chile,* [2]*University of Maryland,* [3]*Universidad De Cordoba, Argentina.*
9:00 AM - 2:00 PM

In this work we summarize recent results concerning a population of spirals hosting an AGN and at the same type exhibit low surface brightness (LSB) disks. The galaxies, extracted from the SDSS DR-4, show interesting properties suggesting that LSB galaxies dynamically prevent the formation/activation of the central black hole. This stability seems to have roots in the large fraction of dark matter in LSB galaxies and also in the statistical isolation in which they are embedded in the large scale structures.

441.13 – **A New Probe of the Distribution of Dark Matter in Galaxies**

Sukanya Chakrabarti[1]

[1]*Florida Atlantic University.*
9:00 AM - 2:00 PM

The scale radius of dark matter halos is a critical parameter for specifying the density distribution of dark matter, and is therefore a fundamental parameter for modeling galaxies. We develop here a novel, observationally motivated probe to quantitatively infer its value. We demonstrate that disturbances in the extended atomic hydrogen gas disks of galaxies can be used to infer the scale radius of dark matter halos. Our primary metric is the phase of the *m=1* mode of the disturbance in the outskirts of the gas disk, which we take to be produced by a tidal interaction. We apply the method to the Whirlpool Galaxy, which has an optically visible satellite. We explore potential degeneracies due to orbital inclination and initial conditions and find our results to be relatively insensitive to these considerations. Our method of tracing the dark potential well through observed disturbances in outer gas disks is complementary to gravitational lensing, which primarily probes the inner regions of dark matter halos.

441.14 – **A Search For Lyman-alpha Halos Around Lyman-alpha Emitters At Z=2 And Z=3**

Alex Hagen[1], R. Ciardullo[1], J. Feldmeier[2], C. Gronwall[1], MUSYC Team

[1]*Pennsylvania State University,* [2]*Youngstown State University.*
9:00 AM - 2:00 PM

In the high-redshift universe, galactic inflows and outflows are ubiquitous, and it is expected that many galaxies will be surrounded by large amounts of neutral hydrogen. Recently Steidel et al. (2011) has presented evidence in support of this hypothesis, via the detection of large (~ 80 kpc) diffuse Lyman-alpha emitting halos in a sample of z~2.6 Lyman-break galaxies. Presumably, this Lyman-alpha emission is due to resonant scattering within the neutral circum-galactic medium. To further investigate this phenomenon, we have stacked the images of the z~2.1 and z~3.1 Ly-alpha emitting galaxies (LAEs) identified in the wide-field surveys of Gronwall et al. (2007), Guaita et al. (2010) and Ciardullo et al. (2011). We show that to perform such a co-addition, attention must be paid to both the systematics of flat-fielding and the contribution of the extended point spread function, and that obtaining the true surface brightness limits of a stacked image requires careful modeling. Our preliminary analysis of 233 LAEs at z~3.1 and 208 galaxies at z~2.1 yields no evidence for the existence of diffuse Ly-alpha surrounding these low-luminosity objects. We discuss the implications for this null result and speculate on the possible systematic luminosity dependence of the neutral envelopes.

441.15 – **Galactic Center Inner Galaxy Dust Clouds In The Infrared And Submillimeter**

Volker Tolls[1], H. A. Smith[1], A. A. Stark[1], M. Etxaluze-Azkonaga[1], C. L. Martin[2], K. Tchernyshyov[2]

[1]*Harvard-Smithsonian, CfA,* [2]*Oberlin College.*
9:00 AM - 2:00 PM

The inner few hundred parsecs of the Galaxy form the Central Molecular Zone (CMZ) - the densest concentration of gas and dust in the Galaxy, including the massive black hole at its center. 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 CLUMPS, within which are high velocity regions called Inner Galactic Gas Clouds (IGGC). We are using Herschel HIFI and PACS [CI], [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 to investigate the physical conditions and processes in Clump 1 and Clump 2. These clumps are of particular interest because they show very little star formation activity, contrary to their counterparts ELSEWHERE in the CMZ. This poster will present the current status of our ongoing analysis, which is focused on the gas knots IGGC 7 and 25 in Clump 1 and IGGC 16, 19, and 23 in Clump 2.

441.16 – **Environmental Effects On Galaxy Evolution In Semi-analytic Models**

Jaehyun Lee[1], I. Jung[1], S. Yi[1]

[1]*Yonsei University, Korea, Republic of.*
9:00 AM - 2:00 PM

We have investigated the evolution of galaxy morphology and its mixture in various halo environments by taking advantages of N-body simulations and semi-analytic approach. Dark matter halos have different growth histories depending on the long-range density (voids vs clusters). Since dynamical properties of dark matter halos decide their merger timescales and galaxy properties residing in the halos, different dark matter halo assemblies make different galaxy merger histories. Thus, it is expected that galaxies in voids and clusters may show different evolutionary histories and morphology mixtures because galaxy mergers play a pivotal role in the galaxy morphology transformation. To examine it, dark matter halo merger trees in various density regions are extracted from N-body simulations, and the evolutionary histories of galaxies are computed with our semi-analytic model code based on the N-body backbones. We present the difference of evolutionary histories and morphology mixtures of galaxies that reside in voids and dense regions.

441.17 – **Galaxy Structure in the Ultraviolet: Case studies for Galaxy Evolution**

Violet Mager[1], C. Conselice[2], M. Seibert[3], C. Gusbar[1], R. Windhorst[4], B. Madore[3]

[1]*Ohio University,* [2]*University of Nottingham, United Kingdom,* [3]*Carnegie Observatories,* [4]*Arizona State University.*
9:00 AM - 2:00 PM

The majority of high redshift galaxies appear similar to a relatively rare subset of low redshift irregular and peculiar galaxies whose morphologies are pathological due to mergers or interactions. The observed increase in the percentage of merging/interacting galaxies with redshift supports models of hierarchical galaxy formation. Detailed comparisons of galaxies as a function of redshift are essential to learn how galaxies assemble and evolve over time. These comparison studies are complicated by the fact that galaxies can look substantially different at shorter wavelengths than at longer ones. This leads to a "morphological k-correction" for a given galaxy between different rest-frame wavelengths. This is particularly important in studies of high redshift galaxies, as band-pass shifting will cause light originally emitted in the UV to be shifted as far as the IR. This raises questions about how much of the irregular/peculiar morphologies seen in high redshift studies are simply due to band-pass shifting, and not real differences in galaxy type. This is particularly important when comparing the UV to the optical or IR, as galaxy stellar energy distributions change drastically short-ward of the Balmer Break (< 360 nm), and UV-bright star-forming regions dominate morphologies that appear smoother at redder wavelengths. We thus calculate a morphological k-correction by quantifying the galaxy structure of several thousand nearby galaxies observed with GALEX (Galaxy Evolution Explorer) in the UV, via their "CAS parameters" (Concentration, Asymmetry, Clumpiness). Funded by a grant through NASA.

441.18 – **Moving Mesh Cosmological Simulations: Characteristics Of Galaxies And Halos**

Dusan Keres[1], M. Vogelsberger[2], D. Sijacki[2], V. Springel[3], L. Hernquist[4]

[1]*Theoretical Astrophysics Center, UC Berkeley,* [2]*ITC/Harvard,* [3]*HITS, Germany,* [4]*Harvard University.*
9:00 AM - 2:00 PM

We present cosmological hydrodynamic simulations of galaxy formation with the new moving-mesh code AREPO, which promises higher accuracy compared with the traditional SPH technique that has been widely employed for this problem. We use the same initial conditions, set of physics and gravity solver to compare these results to the ones with well-tested SPH code GADGET-3 which enables us to cleanly test the differences in hydrodynamics. We find that AREPO leads to significantly higher star formation rates for galaxies in massive halos enabled by a more efficient cooling of the hot halo gas. Furthermore, galaxies in AREPO show more extended gaseous disks, which also feature a thinner and smoother morphology than their GADGET counterparts. Consequently, galaxies formed in AREPO have higher specific angular momentum than their SPH correspondents.

We discuss the causes of these differences which can be connected to shortcomings of the standard SPH implementation. We point out that AREPO can be readily applied to simulations of galaxy formation in a cosmological context where, for a given mass resolution, it requires similar runtimes but offers much higher accuracy than GADGET-3. Our findings also raise questions about some of the previous galaxy formation studies using traditional SPH implementations.

441.19 – **Compact, Dispersion-dominated, Star-forming Galaxies at z~2**

Sarah Newman[1], R. Genzel[2]

[1]*UC Berkeley,* [2]*MPE, Germany.*
9:00 AM - 2:00 PM

Using SINFONI/VLT AO IFU spectroscopy, we observe 13 star-forming, compact and dispersion-dominated z~2 galaxies. We find non-trivial velocity gradients in 11 of these galaxies, including those that appeared to have little rotation based on earlier seeing-limited data. In comparison to rotation-dominated disk-like galaxies from our sample at z~2, these dispersion-dominated systems are younger, more compact, more gas rich, and have lower dynamical masses and gas-phase metallicities. We also find that on average, the dispersion-dominated galaxies have a larger fraction of broad/narrow Ha emission due to star-formation driven winds. This broad emission is likely due to the larger star-formation surface densities of these systems. Indeed, we find a possible trend of increasing broad emission fraction with sigma-SFR, with a threshold sigma-SFR ~ 1 Msol/yr/kpc^2 (corresponding to a molecular gas surface density of 1000 Msol/pc^2) for significant outflows.

441.20 – **A Synthesis Of Cosmic X-ray And Infrared Background**

Yong Shi[1], G. Helou[1], L. Armus[1], S. Stierwalt[1]

[1]*California Institute Of Technology.*
9:00 AM - 2:00 PM

We present a synthesis model of cosmic IR and X-ray background, with the goal to derive a complete census of cosmic evolution of star formation (SF) and black-hole (BH) growth by complementing advantages of X-ray and IR surveys to each other. By assuming that individual galaxies are experiencing both SF and BH accretion, our model decomposes the total IR LF into SF and BH components while taking into account the luminosity-dependent SED and its dispersion of the SF component, and the extinction-dependent SED of the BH component. The best-fit parameters are derived by fitting to the number counts and redshift distributions at X-ray including both hard and soft bands, and mid-IR to submm bands including IRAS, Spitzer, Herschel, SCUBA, Aztec and MAMBO. Based on the fit result, our models provide a series of predictions on galaxy evolution and black-hole growth. For evolution of infrared galaxies, the model predicts that the total infrared luminosity function is best described through evolution in both luminosity and density. For evolution of AGN populations, the model predicts that the evolution of X-ray LF also shows luminosity and density dependent, that the type-1/type-2 AGN fraction is a function of both luminosity and redshift, and that the Compton-thick AGN number density evolves strongly with redshift, contributing about 20% to the total cosmic BH growth. For BH growth in IR galaxies, the model predicts that the majority of BH growth at z>1 occurs in infrared luminous galaxies and the AGN fraction as a function of IR survey is a strong function of the survey depth, ranging from >50% at bright end to below 10% at faint end. We also evaluates various AGN selection techniques at X-ray and IR wavelengths and offer predictions

for future missions at X-ray and IR.

441.21 – **Measuring Radial Velocities of Extragalactic Planetary Nebulae**

Farris Gillman[1], K. A. Herrmann[2], R. Ciardullo[3]

[1]*Yale University,* [2]*Lowell Observatory,* [3]*Pennsylvania State University.*
9:00 AM - 2:00 PM

Planetary Nebulae (PNe) are excellent kinematic probes of old stars in nearby galaxies. They are extremely bright in [O III], present in stellar populations with ages between 0.1 and 10 Gyr, and their radial velocities can be measured to ~3 km/s precision with fiber-fed spectrographs. Narrow-band imaging has been used to identify between 40 and ~500 PN candidates in six nearby spirals (IC 342, M74, M94, M101, NGC 2403, and NGC 6946), as well as >640 possible PNe in the Virgo Cluster. We have recently obtained spectra of a large sample of these extragalactic PN candidates using the Hydra multi-fiber spectrograph on the WIYN telescope. Here we describe the details of applying various IRAF tasks to reduce more than 10,100 spectra (including sky spectra and objects targeted multiple times) and to measure radial velocities and uncertainties. In each of the spirals, the PN velocities clearly show rotation at a speed slightly less than the gas, demonstrating the presence of asymmetric drift. The spectra from the targets in the Virgo Cluster fields are a mixture of true PNe and background Lyman Alpha Emitting galaxies (LAEs). The PN velocities and LAE galaxy spectra will be further analyzed elsewhere.

This research was part of the NAU summer REU program and we gratefully acknowledge funding from the National Science Foundation (AST-1004107).

441.22 – **Star-formation and LLAGN in Early-Type Galaxies**

Kristina Nyland[1], L. Young[1], J. Wrobel[2], R. Morganti[3], M. Sarzi[4], M. Cappellari[5], R. McDermid[6], D. Krajnovic[7], E. Emsellem[7]

[1]*New Mexico Tech,* [2]*NRAO,* [3]*ASTRON, Netherlands,* [4]*University of Hertfordshire, United Kingdom,* [5]*University of Oxford, United Kingdom,* [6]*Gemini Observatory,* [7]*European Southern Observatory, Germany.*
9:00 AM - 2:00 PM

We present the preliminary results for a project which will ultimately provide the first accurate, statistical picture of the relative importance of Low-Luminosity Active Galactic Nuclei (LLAGN) and star formation (SF) in the ATLAS-3D sample (Cappellari et al. 2011) of 260 early-type galaxies (ETGs). The sample has a host of photometric and integral-field spectroscopic measurements already available in the optical and millimeter regimes, making it an ideal sample to draw from for galaxy evolution studies. We will use this multiwavelength, ancillary data in concert with our deep (~25 micro-Jy per beam rms), multifrequency radio continuum observations from the newly-upgraded EVLA to distinguish between the dominant nuclear emission mechanism, SF or

LLAGN, in ETGs. At this time, we present the goals and methodology of our project as well as the results of a pilot EVLA study of a sub-sample of 20 ATLAS-3D galaxies observed at 1.4 and 5 GHz chosen to have a variety of CO, IR and radio properties. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

441.23 – **Gas, Stars and Star Formation in ALFALFA Dwarf Galaxies**

Shan Huang[1], M. Haynes[1], R. Giovanelli[1], J. Brinchmann[2], S. Stierwalt[3], S. Neff[4]
[1]*Cornell University,* [2]*Leiden University, Netherlands,* [3]*California Institute of Technology,* [4]*NASA GSFC.*
9:00 AM - 2:00 PM

We examine the global properties of the stellar and HI components of 229 low HI mass dwarf galaxies extracted from the ALFALFA survey, including a complete sample of 176 galaxies with HI masses < $10^{7.7}$M⊙ and HI line widths < 80 km s^{-1}. SDSS data are combined with photometric properties derived from GALEX to derive stellar masses ($M*$) and star formation rates (SFRs) by fitting their UV-optical spectral energy distributions (SEDs). In optical images, many of the ALFALFA dwarfs are faint and of low surface brightness; only 56% of those within the SDSS footprint have a counterpart in the SDSS spectroscopic survey. A large fraction of the dwarfs have high specific star formation rates (SSFRs) and estimates of their SFRs and $M*$ obtained by SED fitting are systematically smaller than ones derived via standard formulae assuming a constant SFR. The increased dispersion of the SSFR distribution at $M* \leq 10^8$M⊙ is driven by a set of dwarf galaxies that have low gas fractions and SSFRs; some of these are dE/dSphs in the Virgo cluster. The imposition of an upper HI mass limit yields the selection of a sample with lower gas fractions for their $M*$ than found for the overall ALFALFA population. Many of the ALFALFA dwarfs, particularly the Virgo members, have HI depletion timescales shorter than a Hubble time. An examination of the dwarf galaxies within the full ALFALFA population in the context of global star formation laws is consistent with the general assumptions that gas-rich galaxies have lower star formation efficiencies than do optically selected populations and that HI disks are more extended than stellar ones.

441.24 – **Homologies in Physics and Astrophysics**

David F. Bartlett[1], J. P. Cumalat[1]
[1]*Univ. of Colorado.*
9:00 AM - 2:00 PM

The genes of humans and chimpanzees are homologs. These genes are - in large measure - identical. From this detailed observation, we naturally suppose that both species evolved from a common ancestor. In particle physics the ordinary observed particles and their superymmetric partners are thought to be homologs, generated by a common “ancestor” , the Higgs particle. Experiments at CERN currently are testing this comfortable analogy of physics with biology. Neither the Higgs boson nor any supersymmetric particle has yet been found.

We speculate that a variety of objects are homologs - evidence of an as yet undeveloped quantum theory of gravity to replace Dark Matter. A purely astronomical homology is the V_c - σ_o relation which places nearly spherical elliptical galaxies just above well-formed spirals (SA & SB). Here the asymptotically- flat, circular velocity V_c is observed to be between 1 and 2 times the central bulge velocity dispersion σ_o over the range 60 km/s< σ_o <400 km/s (Ferrarese 2002, Fig 3). The V_c - σ_o relation is difficult to explain with self-consistent equilibrium galaxy models (Courteau et al 2007). Here we give an explanation based on the Sinusoidal Potential, a non-Newtonian potential in which $\varphi = -GM \cos[k_o r]/r$ and $k_o = 2\pi/400$ pc.

We relate the lower limit of 60 km/s to the thermal velocity of protons at the” Broadhurst/Hirano & Hartnett” lookback redshift $Z=10^{5.6}$. This is the redshift where what was 400 pc then expands to 128 h^{-1} Mpc today. Further, at this Z the temperature of the universe was close to the Hartree Energy of 2 times 13.6 eV, an energy where protons have an rms speed of about 60 km/s.

441.25 – **The X-ray Properties of Local Group Dwarf Galaxies**

R. Mitch Verboncoeur[1], C. Fuse[1]
[1]*Rollins College.*
9:00 AM - 2:00 PM

As part of a larger investigation into the environmental effects on low- and intermediate-luminosity galaxies, we have conducted a comprehensive analysis of the dwarf galaxies in the Chandra X-Ray Observatory archives. The low luminosities of dwarf galaxies make them difficult objects to observe, therefore the sample galaxies are primarily limited to the Local group. Because of their relatively low mass, dwarf galaxies are more prone to be affected by environmental influences. Thus, an analysis of the X-ray features and properties of dwarf galaxies may provide valuable insight into galaxy evolution.

The diffuse X-ray gas halos and the X-ray point sources associated with the dwarf galaxies were analyzed. While many dwarf galaxies have neutral gas reservoirs and low levels of star formation, the sample dwarf galaxies typically contain less than eight X-ray point sources. The dwarf galaxies have small diffuse gas halos confined to the optical extent of each object. Future research will examine whether dwarf galaxies are scaled-down versions of large, luminous galaxies and whether the down scaling of features is the reason for the lack of diffuse gas and the relatively small number of point sources.

441.26 – **Galaxy Transformation and Environment in the ORELSE Survey**

Roy R. Gal[1]
[1]*Univ. Of Hawaii.*
9:00 AM - 2:00 PM

The Observations of Redshift Evolution in Large Scale Environments (ORELSE) Survey is mapping 20 structures at z~1, with optical and near-IR photometry, extensive spectroscopy, and X-ray and radio data. We present results on the intimate connection between environment and galaxy colors, morphologies, star formation, and AGN activity.

441.27 – **Merging Features and Optical-Near Infrared Color Gradients of Early-type Galaxies**

Duho Kim[1], M. Im[1]
[1]*Seoul National University, Korea, Republic of.*
9:00 AM - 2:00 PM

It has been suggested that merging plays an important role in the formation and the evolution of early-type galaxies (ETGs). Optical-NIR color gradients of ETGs in high density environments are found to be less steep than those of ETGs in low density environments, hinting frequent merger activities in ETGs in high density environments. In order to examine if the flat color gradients are the result of dry mergers, we studied the relations between merging features, color gradient, and environments of 198 low redshift ETGs selected from Sloan Digital Sky Survey (SDSS) Stripe82. Near Infrared (NIR) images are taken from UKIRT Infrared Deep Sky Survey (UKIDSS) Large Area Survey (LAS). Color(r-K) gradients of ETGs with tidal features are a little flatter than relaxed ETGs, but not significant. We found that massive (>$10^{11.3}$ M⊙) relaxed ETGs have 2.5 times less scattered color gradients than less massive ETGs. The less scattered color gradients of massive ETGs could be evidence of dry merger processes in the evolution of massive ETGs. We found no relation between color gradients of ETGs and their environments.

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442 – Black Holes & GRBs

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

442.01 – **Theoretical Considerations for Black Hole Formation in Supernova Ejecta**

Andrew Hayes[1], N. F. Comins[1]
[1]*University of Maine.*
9:00 AM - 2:00 PM

We present a method for detecting regions within a dataset from a simulation of a high energy astrophysical event, such as a supernova, that are unstable to gravitational collapse. This method can be used where the resolution, spatial domain, and/or time span of the simulation may not be sufficient to evolve the region to gravitational collapse natively. The accuracy of the method is demonstrated by applying it to various spherical mass distributions whose stability is known through other means. We have already used the method in the analysis of datasets from three simulations, with negative results. We also discuss the consequences of the ongoing production of low-mass, high-velocity black holes.

442.02 – **A Dynamical Model to Track the SMBBH's Path Towards Coalescence**

Eva Martinez-Palafox[1], O. Valenzuela[1]
[1]*IA-UNAM, Mexico.*
9:00 AM - 2:00 PM

We follow the evolution of supermasive binary black holes (SMBBH) in the last stages of their evolution, a few pc. We have used a semianalytical model that includes a BHs binary system with triple disks, the mass added to the circumbinary disk due to cosmic accretion and the corresponding exchange of angular momentum between accretion, mass transfer and orbital motion. While the circumbinary disk removes angular momentum, the cosmological mass transfer adds some fraction of its angular momentum to the orbital angular momentum of the SMBBH.

442.03 – **A Very Close Binary Black Hole in 3C 66B and its Black Hole Merger**

Satoru Iguchi[1]
[1]*NAOJ, Japan.*
9:00 AM - 2:00 PM

Recent observational results show possible evidence that Binary Black Holes (BBHs) exist in the center of giant galaxies and may merge to form a supermassive black hole in the process of their evolution. Clarifying the BBH formation mechanism will have an enormous impact on the study of the galaxy merger in galaxy formation process, as well as the study of the black hole merger in supermassive black hole formation process and the detection of gravitational waves at the BBH orbital decay phase. We first detected a periodic flux variation on a cycle of 93±1 days from the 3-mm monitoring observations of a giant elliptical galaxy 3C 66B, with which an orbital motion with a period of 1.05±0.03 years had been observed. The detected signal period is shorter than the orbital period; however it can be explained by the Doppler-shifted modulation associated with the orbital motion of a BBH. Assuming that the BBH has a circular orbit and that the jet axis is parallel to the binary angular momentum, our observational results demonstrate the presence of a very close BBH that has a binary orbit with an orbital period of 1.05±0.03 years, an orbital radius of $(3.9\pm1.0)\times10^{-3}$ pc, an orbital separation of $(6.1^{+1.0}_{-0.9})\times10^{-3}$ pc, the larger black hole mass of $(1.2^{+0.5}_{-0.2})\times10^{9}$ $M_{\odot}$, and the smaller black hole mass of $(7.0^{+4.7}_{-6.4})\times10^{8}$ $M_{\odot}$. Since it is supposed that a black hole emits strong gravitational waves in the final stage of merger, the decay time of a BBH estimated from the gravitational radiation is $(5.1^{+60.5}_{-2.5})\times10^{2}$ years. Our observational results show that the black hole collisions may have important implications for the formation of a supermassive black hole in the evolution process.

442.04 – **Dynamical Constraints on the Black Hole in Ultraluminous X-ray Source NGC 1313 X-2**

Jifeng Liu[1], J. Orosz[2], J. N. Bregman[3]
[1]*Harvard-Smithsonian, CfA,* [2]*SDSU,* [3]*University of Michigan.*
9:00 AM - 2:00 PM

Dynamical mass measurements hold the key to answering whether ultraluminous X-ray sources (ULXs) are intermediate mass black holes (IMBHs) or stellar mass black holes with special radiation mechanisms. NGC1313 X-2 is so far the only ULX with HST light curves, the orbital period, and the black hole's radial velocity amplitude. We constrain its black hole mass and other parameters by fitting observations to a binary light curve code with accommodations for X-ray heating of the accretion disk and the secondary. Given the dynamical constraints from the observed light curves and the black hole radial motion, the presence of hydrogen lines in the optical spectra, and the observed stellar environment age, the only acceptable models are those with 40-50 Myrs old intermediate mass secondaries in their helium core and hydrogen shell burning phase filling 40%-80% of their Roche lobes. The black hole can be a massive black hole of a few tens of solar masses that can be produced from stellar evolution of low metalicity stars, or an IMBH of a few hundred to above 1000 solar masses if its true radial velocity is 5 times lower than derived from the He II disk emission line. Further observations with HST can better measure the black hole radial motion and the light curves and determine whether NGC1313 X-2 is a stellar black hole or an IMBH.

442.05 – **CXO M31 J004253.1+411422: The First Ultra-luminous X-ray Transient In M 31**

A. Kaur[1], M. Henze[2], F. Haberl[2], W. Pietsch[2], J. Greiner[2], A. Rau[2], D. Hartmann[1], G. Sala[3], M. Hernanz[4]
[1]*Clemson University,* [2]*Max-Planck-Institut fur extraterrestrische Physik, Giessenbachstrasse, Germany,* [3]*Department of Fisica i Enginyeria Nuclear, EUETIB (UPC-IEEC), Comte d'Urgell 187,, Spain,* [4]*Institut de Ciencies de 1'Espai (CSIC-IEEC), Campus UAB, Facultat Ciencies, C5 parell 2on, Spain.*
9:00 AM - 2:00 PM

We report on Chandra/Swift/XMM-Newton observations of an ultraluminous X-ray (ULX) source in M 31 discovered by Chandra-HRC-I on December 17, 2009. The light curve was established using follow up observations with Swift-XRT and XMM-Newton. The X-ray spectrum is best fit by a combination of a thermal component with kT ~ 1 keV and a non-thermal component (single powerlaw) with photon index ~ 2.6. The maximum unabsorbed total luminosity derived from this data is 3.8×10^{39} erg/s, and subsequently decreased to 0.6×10^{39} erg/s on a time scale of one month. The luminosity exhibits a FRED (Fast Rise Exponential Decay) pattern with an exponential time constant of 32 days. The underlying source for this ULX is likely a 14 M_{sun} black hole, accreting near the Eddington limit.

442.06 – **Grb 110328a/swift J164449.3+573451: The Tidal Obliteration Of A Deeply Plunging Star?**

John K. Cannizzo[1], E. Troja[2], G. Lodato[3]
[1]*NASA/GSFC/CRESST/UMBC,* [2]*NASA Postdoctoral Program,* [3]*Universita degli Studi di Milano, Italy.*
9:00 AM - 2:00 PM

We examine the tidal disruption event scenario to explain Sw 1644+57, a powerful and persistent X-ray source which suddenly became active as GRB 110328A. The precise localization at the center of a z=0.35 galaxy argue for activity of the central engine as the underlying cause. We look at the suggestion by Bloom et al of the possibility of a tidal disruption event (TDE). We argue that Sw 1644+57 cannot be explained by the traditional TDE model in which the periastron distance is close to the tidal disruption radius - three independent lines of argument indicate the orbit must be deeply plunging or else the powerful jet we are observing could not be produced. These arguments stem from (i) comparing the early X-ray light curve to the expected theoretical fallback rate, (ii) looking at the time of transition to disk-dominated decay, and (iii) considering the TDE rate. Due to the extreme excess in the tidal force above that which would be required minimally to disrupt the star in a deeply plunging orbit at periastron, we suggest this scenario might be referred to more descriptively as a TOE (tidal obliteration event) rather than a TDE.

442.07 – **Tapping into the Energy of Black Holes**

Patrick M. Motl[1], L. Lenher[2], S. Liebling[3], C. Palenzuela[4], D. Neilsen[5], E. Hirschmann[5]
[1]*Indiana University Kokomo,* [2]*The Perimeter Institute, Canada,* [3]*Long Island University,* [4]*CITA, Canada,* [5]*Brigham Young University.*
9:00 AM - 2:00 PM

The extraction of rotational energy from a spinning black hole via the Blandford-Znajek mechanism has long been understood as an important component in models to explain energetic jets from compact astrophysical sources. Here we show more generally that the kinetic energy of the black hole, both rotational and translational, can be tapped, thereby producing even more luminous jets powered by the interaction of the black hole with its surrounding plasma. We study the resulting Poynting jet that arises from single boosted black holes and binary black hole systems. In the latter case, we find that increasing the orbital angular momenta of the system and/or the spins of the individual black holes results in an enhanced Poynting flux.

442.08 – **Uncovering the Low Energy Emission of Fermi LAT Transients**

Veronique Pelassa[1], Fermi LAT and GBM collaborations
[1]*NSSTC - MSFC/UAH.*
9:00 AM - 2:00 PM

Fermi Large Area Telescope (LAT) standard science analyses are restricted to well-reconstructed events, with energies above 100 MeV. Applying a less restrictive selection allows one to recover the high photon statistics between 30 MeV and 100 MeV in the prompt emission from Gamma-Ray Bursts (GRB) and Solar Flares (SFL), thus filling the gap between the *Fermi* Gamma-ray Burst Monitor (GBM) and the LAT in standard analysis mode. We present here results showing the power of this technique to extract both lightcurves and energy spectra of the transients in this energy range.

442.09 – **Probing the Circumburst Environment & Jet of GRB 091018A : Modeling the Synchrotron Peak - Cooling Break Cross Over**

Apurva Oza[1], D. E. Reichart[1], A. Trotter[1], UNC GRB team
[1]*UNC Chapel Hill.*
9:00 AM - 2:00 PM

We focus on continuing the modeling of Gamma-ray Burst (GRB) 091018. Our data is mostly collected across 4 bands (BVRI) from PROMPT (Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes) approximately 4.1 hours after the trigger. We have added NIR, UVOT, X-ray, and more optical points to our datasets. Our baseline fit has accurately modeled the shocks in the jet, attributed to either energy injection or density variation. After rejecting the original assertion of dust evolution in the early BVRI bands by linking extinction parameters with Galapagos (a software that employs genetic algorithms to output the best fit model with our circumburst GRB parameters), we have settled on a model with the circumburst density index k at -2.87 which suggests a wind-blown medium of k=-2. In addition to k, the results of our baseline fit indicate that we have localized the cooling break - synchrotron peak crossover during early UVOT times. This cross-over will yield interesting physical information about the circumburst medium and jet of the GRB at early times. With the unique linking capability in Galapagos, we have furthered our analysis to test variance in our k value across time slices. The host galaxy will be modeled after observation using the 9.2 m telescope SALT. We acknowledge and appreciate the support of the NASA Space Grant and NSF to carry out this research.

442.10 – **New GRB Candidates as Detected by the Fermi Gamma-ray Space Telescope, January-June 2011**

Rebecca Robinson[1]
[1]*Michigan State University.*
9:00 AM - 2:00 PM

After analyzing data collected by the Fermi Gamma Ray Space Telescope GLAST

Burst Monitor (GBM), operated by NASA in cooperation with the US Department of Energy, we focus on gamma ray events from January to June in the year 2011. A portion of these events were detected in concordance with events that have already been reported, and the others are to be announced in this report. For each event, an energy spectrum was generated using a trigger-search computer algorithm and these spectra were divided into several categories for further analysis. In some cases, intriguing spectral lines, including a 511 keV line, were detected; implications and analysis of these known and previously unknown detections are discussed in this report.

443 – Make Way for Lab Astro!

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

443.01 – **NIST Atomic Spectroscopy Databases in Support of Astronomy**

Joseph Reader[1], A. Kramida[1], Y. Ralchenko[1]

[1]*National Institute of Standards and Technology.*

9:00 AM - 2:00 PM

Joseph Reader[1], Alexander Kramida[1], Yuri Ralchenko[1]

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The NIST Atomic Spectroscopy Data Center maintains a number of online databases supporting astronomical observations of atomic spectra. The available numerical and bibliographic databases can be accessed from the NIST Physical Measurement Laboratory website www.nist.gov/pml/data/atomspec.cfm. The largest one, the Atomic Spectra Database (ASD), contains wavelength and energy level data for nearly 180,000 spectral lines including 73,400 oscillator strengths. ASD also includes 92,500 energy levels for various ions of 89 elements. In addition to tabular data, ASD can generate dynamic Grotrian diagrams and Saha/LTE spectra, which can be tailored to the user's needs. We continue to systematically expand this database according to needs of the astrophysics and fusion energy science communities. Our bibliographic databases for atomic spectra are updated about every two weeks; they serve as a valuable resource in searching for the latest data. We also provide online non-LTE codes for plasma modeling. Our compilations of spectral data are largely oriented to the needs of astronomers. Recently completed are extensive compilations for Ar, Cr, Ti, and Ni, and a new compilation for Ca is in progress. Recent updates of line lists and transition probabilities include data for H, He, Li, Be, B, C, N, F, Ne, Na, Mg Al, Cl, Sr, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Cs, and Ba. We welcome suggestions from astronomers regarding spectra to be compiled and added to the online databases. Spectral atlases of Pt/Ne and Th/Ar hollow cathode lamps for wavelength calibration of astronomical spectrometers can also be found at his website.

Our Data Center is supported by NASA (agreement NNH09AL771) and by the Office of Fusion Energy Sciences of the U. S. Department of Energy.

443.02 – **Experimental Atomic Spectroscopy At NIST In Support Of Astronomy**

Gillian Nave[1], C. J. Sansonetti[1], S. L. Redman[1]

[1]*NIST.*

9:00 AM - 2:00 PM

The Atomic Spectroscopy Group at the National Institute of Standards and Technology (NIST) has equipment to measure atomic wavelengths and oscillator strengths of astrophysical interest over a wide spectral range. Our 2-m Fourier transform (FT) spectrometer covers wavelengths from 230 nm to 5500 nm at a resolving power of over a million. It has been used to measure calibration data for ground-based astronomical spectrographs, including infrared atlases of Th/Ar and U/Ne hollow cathode lamps and measurements of iodine absorption cells that calibrate many of the spectrographs used for exoplanet searches. Our ultraviolet FT spectrometer covers the range from 140 nm to 900 nm with a resolving power of over a million at 200 nm. Below 140 nm, our 10.7 m normal incidence vacuum spectrograph has been used to provide calibration data for three spectrographs on the Hubble Space Telescope (GHRS, STIS and COS). Although originally designed for use with photographic plates, we have begun using this instrument with phosphor image plates as detectors. These provide a linear intensity response throughout the vacuum ultraviolet, enabling us to measure branching ratios in Fe II and the change in spectral line intensities of Pt/Ne hollow cathode lamps as they age. Data from all three instruments are currently being analyzed to obtain comprehensive descriptions of the spectra of Fe II and Cr II covering wavelengths from 90 nm to 5500 nm.

Much of this work has been partly funded by NASA, most recently under agreement NNH11AQ551 to analyze spectra of iron-group elements. Such support is crucial to the continuation of this work at NIST, much of which is of little interest in basic atomic physics but is vital for the interpretation of astrophysical spectra. We are seeking collaborations with astronomers who can assist us in determining future research directions.

443.03 – **Atomic Data For Lowly Ionized Fe-peak Species**

Manuel Bautista[1], V. Fivet[1], C. Ballance[2], P. Quinet[3]

[1]*Western Michigan University,* [2]*Auburn University,* [3]*Universite de Mons, Belgium.*

9:00 AM - 2:00 PM

Several of the most important astronomical topics today that involve UV and optical astronomical spectroscopy require detailed understanding of singly and doubly ionized iron-peak species (Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu). Yet, our present knowledge of the atomic physics and spectra is lagging behind the avalanche of high quality spectra arising from these ions.

We are carrying out a systematic study of each of these species aiming to provide complete spectral models containing radiative rates and collision strengths. The present atomic computations employed a combination of state of the art atomic physics methods, e.g. relativistic Hartree-Fock, the Thomas-Fermi-Dirac potential, and Dirac-Fock computation of A-values and R-matrix with intermediate coupling frame transformation and Dirac R-matrix. We study the advantages and shortcomings of each method.

The obtained spectral data is then benchmarked against observed astronomical spectra. It has been found that the Dirac R-matrix collision strengths yield excellent agreement with observations. By contrast, LS-coupling R-matrix results fail to yield accurate effective collision strengths at around 104 K, despite using very large configuration expansions, because of the limited treatment of spin-orbit effects in the near threshold resonances of the collision strengths.

The present models are in very good agreement with observed emission spectra, in contrast with previous models. The present work demonstrates that accurate atomic data for low ionization iron-peak species is now within reach.

443.04 – **Radiative and Collision Rates for Transitions in Mg VI and Si VIII**

Swaraj S. Tayal[1]

[1]*Clark Atlanta Univ..*

9:00 AM - 2:00 PM

The improved radiative and collision atomic parameters calculation for nitrogen like Mg VI and Si VIII ions have been performed using the B-spline Breit-Pauli R-matrix method. The flexible non-orthogonal sets of spectroscopic and correlation radial functions are employed for an accurate representation of the target states and scattering functions. The close-coupling expansion includes 76 bound levels of Mg VI and Si VIII covering all possible terms of the ground $2s^22p^3$ and excited $2s2p^4$, $2p^5$, $2s^22p^23s$, $2s^22p^23p$, and $2s^22p^23d$ configurations. The calculated excitation energies of the target levels are in excellent agreement with experiment and represent an improvement over the previous calculations. The present results of cross sections are compared with a variety of other close-coupling calculations. The oscillator strengths and transition probabilities for several transitions are in good agreement with other theories and available experimental data. The present cross sections are in good agreement with other theories and experiment for many transitions, but some differences in magnitude and shape for some other transitions are also noted. These data should be useful to interpret the recent ground and space-based observations and to model the solar and other astrophysical plasmas. Our results are estimated to be accurate 20% or better.

This research is supported by NASA under grant NNX11AB62G from the Solar and Heliophysics Program.

443.05 – **New Computation Of The Astrophysical HD-Cooling Function**

Renat Sultanov[1], D. Guster[1], S. K. Adhikari[2]

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[2]*Institute of Theoretical Physics, IFT-UNESP, Sao Paulo, Brazil.*

9:00 AM - 2:00 PM

New thermal rate coefficients for rotational transitions in HD+o-/p-H2 collisions will be presented. Extensive quantum mechanical coupled-channel calculation has been performed. Recently published H2-H2 potential energy surfaces have been applied. Astrophysical HD-cooling function at low-density-limit due to HD+o-/p-H2 collisions is computed with the use of the new thermal rate coefficients. A comparison and analysis with previous results will also be presented.

444 – Star Formation, Dust, Etc.

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

444.01 – **Searching for Low-mass Companions of Cepheids, Part II**

Nancy Remage Evans[1], E. Tingle[1], H. E. Bond[2], G. H. Schaefer[3], B. Mason[4], M. Karovska[1], S. Wolk[1], I. Pillitteri[1], J. DePasquale[1], E. Guinan[5], S. Engle[5]

[1]*SAO,* [2]*STScI,* [3]*Georgia State Univ., The CHARA Array,* [4]*US Naval Obs.,*

[5]*Villanova.*
9:00 AM - 2:00 PM

The formation of a binary/multiple system is an effective way to manipulate angular momentum during the star-formation process. The properties of binary systems (separations and mass ratios) are thus the ``fingerprints'' of the process. Low mass companions are the most difficult to identify particularly for massive stars. We are conducting a snapshot survey of the nearest Cepheids (5 Msun stars) using the Hubble Space Telescope Wide Field Camera 3 (WFC3) to discover possible resolved low mass companions. The color-magnitude combination is the first approach to identifying probable physical companions. The distributions of mass and separation for these stars will be discussed.

Financial suppoet was provided by Hubble grant GO-12215.01-A and the Chandra X-ray Center NASA contract NAS8-03060.

444.02 – **Simulated ALMA Observations of a Low-mass Star Forming Region**

Gilberto Lopez[1]

[1]*Harvard.*
9:00 AM - 2:00 PM

To better understand the quantitative performance of the new ALMA Observatory, we simulate an ALMA observation of a simulated low-mass star forming region. We also compare the properties of the original simulated data cube and the output of the simulated observation. We explore the impact of different observation times and the incorporation of noise and, using tree-based structure analysis tools, analyze size, mass, and virial parameter.

444.03 – **Herschel FIR Spectroscopic Observations of L1448-MM**

Jinhee Lee[1], J. Lee[1], DIGIT Team

[1]*Kyung-Hee University, Korea, Republic of.*
9:00 AM - 2:00 PM

We present the FIR (continuum and line) maps and spectra of L1448-MM at 55 to 210 micron observed with the range scan mode of PACS on the Herschel Space Observatory, as part of the DIGIT key program. L1448-MM was previously known as an embedded Class 0 and prominent outflow source, and a secondary YSO was claimed by the Spitzer images and confirmed by submm interferometric observations. The PACS detected various CO, OH, H_2O, and OI lines. The PACS line and continuum maps show that the emission at shorter wavelengths peaks at the central spatial pixel (the primary YSO position) although the line emission of low energy levels distributes along the outflow direction. According to our excitation analysis, the CO gas has two temperature components (warm and hot) that are tentatively attributed to PDR and shock, respectively. However, the H_2O gas with the rotational temperature of ~200 K seems to trace the shock. Interestingly, the relative strength of OH transitions suggests the IR pumping process dominates in L1448-MM. The gas along the outflow cavities in L1448-MM seems to be heated mainly by shock and UV photons, and relative line luminosities indicate that H_2O and CO are the main coolants of this gas, although cooling by OI and OH cannot be ignored.

444.04 – **Herschel Observations of a Potential Core Forming Clump: Perseus B1-E**

James Di Francesco[1], S. Sadavoy[2], Herschel Gould Belt Survey Team

[1]*Herzberg Inst. of Astrophysics, Canada,* [2]*University of Victoria, Canada.*
9:00 AM - 2:00 PM

We present continuum observations of the Perseus B1-E region from the Herschel Gould Belt Survey. These Herschel data reveal a loose grouping of substructures at 160 − 500 microns not seen in previous submillimetre observations. We measure temperature and column density from these data and select the nine densest and coolest substructures for follow-up spectral line observations with the Green Bank Telescope. We find that the B1-E clump has a mass of about 100 solar masses and appears to be gravitationally bound. Furthermore, of the nine substructures examined here, one substructure (B1-E2) appears to be itself bound. The substructures are typically less than a Jeans length from their nearest neighbour and thus, may interact on a timescale of ~ 1 Myr. We propose that B1-E may be forming a first generation of dense cores, which could provide important constraints on the initial conditions of prestellar core formation. Our results suggest that B1-E may be influenced by a strong, localized magnetic field, but further observations are still required.

444.05 – **The First Stars: Mass Growth Under Protostellar Feedback**

Athena Stacy[1]

[1]*Goddard Space Flight Center.*
9:00 AM - 2:00 PM

We perform three-dimensional cosmological simulations to examine the growth of metal-free, Population III (Pop III) stars under radiative feedback. We begin our simulation at z=100 and trace the evolution of gas and dark matter until the formation of the first minihalo. We then follow the collapse of the gas within the minihalo up to densities of $n = 10^{12}$ cm^{-3}, at which point we replace the high-density particles with a sink particle to represent the growing protostar. We model the effect of Lyman-Werner (LW) radiation emitted by the protostar, and employ a ray-tracing scheme to follow the growth of the surrounding HII region over the next 5000 yr. A disk assembles around the first protostar, and radiative feedback does not prevent further fragmentation of the disk to form multiple Pop III stars. The ionizing and photodissociating radiation leads to heating of the dense gas to several thousand Kelvin, and this warm region expands outward at the gas sound speed. Once the extent of this warm region becomes equivalent to the size of the disk, the disk mass declines while the accretion rate onto the protostars is reduced by an order of magnitude. This occurs when the largest sink has grown to ~20 Msol while the second sink has grown to ~ 7 Msol, and we estimate the main sink will approach an asymptotic value of 30 Msol by the time it reaches the main sequence. Our simulation thus indicates that the most likely outcome is a massive Pop III binary. If Pop III stars were typically unable to grow to more than a few tens of solar masses, this would have important consequences for the occurrence of pair-instability supernovae in the early Universe as well as the Pop III chemical signature in the oldest stars observable today.

444.06 – **Water Vapor MASER Observations of High-mass Star Formation Regions**

Victor Migenes[1], T. Rodriguez[2], M. A. Trinidad[2]

[1]*Brigham Young University,* [2]*University of Guanajuato, Mexico.*
9:00 AM - 2:00 PM

The study of high-mass star formation processes is complicated because the sources are embedded in regions of dense gas and dust, limiting their study to radio and infrared bands. In addition, they form in groups, their evolution is much faster than for low-mass star formation and are distributed much farther away. Our present understanding comes from the study of the ionizing regions in which they are formed via molecular, IR, mm and MASER emission observations.

Low-mass star formation regions seem to be reasonably explained by the disk-YSO-outflow model but it is not completely clear if the same model describes high-mass star formation. Water maser observations have proven to be a valuable tool to find and study this regions. We present and discuss high-sensitivity and high-resolution water MASER and continuum emission observations of some of these regions.

444.07 – **A Numerical Synthesis of Molecular Lines from the UV-heated Outflow walls in the Embedded Protostellar Objects**

Seokho Lee[1], J. Lee[2], Y. Park[1]

[1]*Seoul National University, Korea, Republic of,* [2]*Kyung Hee University, Korea, Republic of.*
9:00 AM - 2:00 PM

An UV-heated outflow wall can reproduce the warm CO emission in the Herschel/PACS observations of embedded protostellar objects. We have developed improved models of Photo Dominated Region (PDR) and Non-LTE line radiative transfer (RT) to synthesize the Herschel FIR observations more accurately and self-consistently. A new (r, δ) coordinate system was used, where the r is the distance from the origin and the δ is z/R^2 in the cylindrical coordinate of (R, z). This is an adequate coordinate system to represent a power-law density of an envelope and a high spatial resolution near the outflow wall. The PDR model solves the FUV continuum radiative transfer, gas energetics, and chemistry simultaneously. A local FUV radiation flux is calculated by using a Monte Carlo method taking anisotropic scattering into account. The RT was developed from the RATRAN code (Hogertheijde & van de Tak 2000) using an accelerated Monte-Carlo method, and it can cope with line overlap effect among multiple molecular and atomic species. These newly developed models can be used to analyze quantitatively the effect of UV-heated outflow walls on the warm molecular lines in the embedded protostellar objects.

444.08 – **Inflow Models of Nearby Cores**

De La Cruz David[1], C. H. De Vries[1], H. G. Arce[2]

[1]*CSU Stanislaus,* [2]*Yale University.*
9:00 AM - 2:00 PM

We obtained observations of nearby (d < 300 pc) isolated pre-stellar and Class 0 cores from the Caltech Submillimeter Observatory. The optically thick HCO+ J=3-2 rotational transition was observed in order to detect the blue-asymmetric infall signature often seen in pre-stellar cores. The asymmetric spectral line profiles were analyzed by using a 1-D radiative transfer model that assumes a uniform infall velocity and a realistic radial excitation profile. The model is able to reproduce the asymmetric line profile in most cases by varying only 5 physical cloud parameters. The analysis was used to obtain a reliable estimate of the infall rate. The sources presented here and observed in the HCO+ J=3-2 rotational transition were B228, CB130 SMM2, OPH MM 126, and RCRA SMM1A. Analysis of these spectra yielded some unexpected results. Our analysis did a good job at fitting the spectral lines in some sources while it performed poorly for others. We observed infall velocities ranging from -1.1, indicating expansion, to 0.4 km/s in these sources and found line center optical depths ranging from 0.03 to 520. The peak excitation temperature for the HCO+ J=3-2 transition was found to range

from 3 to 57 K.

444.09 – **An Analysis of Triggered Star Formation in the G38.91-0.42 Complex**

Michael Alexander[1], H. Kobulnicky[1], K. Arvidsson[2], C. Kerton[3]

[1]*University of Wyoming,* [2]*Adler Planetarium,* [3]*Iowa State University.*

9:00 AM - 2:00 PM

We present an analysis of a star formation region G38.91-0.42 at a distance of ~2.3 kpc that appears to be forming, at most, intermediate-mass stars. We have gathered data from multiple space-based and ground based surveys that covers the entire infrared regime from 1 to 500 um, as well as some millimeter and radio wavelengths. We have constructed a complete picture of star formation by identifying possible main sequence star clusters, young stellar objects (YSOs), and clumps of dense SF material. Over 150 YSOs have been found and classified by fitting model SEDs. We demonstrate a possible correlation between YSO mass and the column density of molecular gas & dust. There is also evidence for an anti-correlation between YSO age and dust column density. Our analysis shows that this region exhibits a much higher ratio of young stage I YSOs to older stage II YSOs suggesting that G38.91-0.42 is extremely young. We have also searched for evidence of triggered star formation near the limb-brightened bubbles/shells seen in mid-IR images. The lack of young YSOs within the the IR bubbles, and the collection of dense gas on the bubbles' rims is broadly consistent with the collect-and-collapse model, where the bubbles are still too young to have formed the next generation of stars. This work represents the first stage of a larger program designed to study triggered star formation in star forming regions covering a wide range of stellar energy and molecular gas properties.

444.10 – **Extended Schmidt Law: Role of Existing Stars in Current Star Formation**

Yong Shi[1], G. Helou[1], L. Armus[1], S. Stierwalt[1], L. Yan[1]

[1]*California Institute Of Technology.*

9:00 AM - 2:00 PM

We propose an ``extended Schmidt law'' with explicit dependence of the star formation efficiency (SFE=SFR/Mgas) on the stellar mass surface density. This relation has a power-law index of 0.48+-0.04 and an 1-sigma observed scatter on the SFE of 0.4 dex, which holds over 5 orders of magnitude in the stellar density for individual global galaxies including various types especially the low-surface-brightness (LSB) galaxies that deviate significantly from the Kennicutt-Schmidt law. When applying it to regions at sub-kpc resolution of a sample of 12 spiral galaxies, the extended Schmidt law not only holds for LSB regions but also shows significantly smaller scatters both within and across galaxies compared to the Kennicutt-Schmidt law.

We argue that this new relation points to the role of existing stars in regulating the SFE, thus encoding better the star formation physics. Comparison with physical models of star formation recipes shows that the extended Schmidt law can be reproduced by some models including gas free-fall in a stellar-gravitational potential and pressure-supported star formation. By implementing this new law into the analytic model of gas accretion in Lambda CDM, we show that it can re-produce the observed main sequence of star-forming galaxies (a relation between the SFR and stellar mass) from z=0 up to z=2.

444.11 – **Dust Acceleration in Radiative Shocks: Seeds of Cosmic Rays?**

Jonathan David Slavin[1]

[1]*Harvard-Smithsonian, CfA.*

9:00 AM - 2:00 PM

Diffusive shock acceleration in fast shocks in the interstellar medium (ISM) appears to be the best candidate for a mechanism to accelerate cosmic rays. However, the means to achieve the initial injection of cosmic ray nuclei with the suprathermal energies that are large enough to facilitate the acceleration to the high energies observed remains a source of difficulty. In addition cosmic ray composition corresponds well with the composition of interstellar dust. Using dust as the source of the cosmic rays can explain many aspects of the galactic cosmic ray observations, but models to date have assumed dust acceleration/destruction in very fast shocks, v(shock) >~ 400 km/s. Such shocks cover a fairly small volume of typical ISM. Here we present the results of models for the acceleration and destruction of grains in radiative shocks with v(shock) = 50 - 200 km/s, which are expected to cover a relatively large volume of the ISM. We find that for certain grain sizes and shock speeds a substantial fraction of the grain mass is returned to the gas phase upstream of the shock with an initial energy corresponding to several hundred to 1000 or so km/s. Such newly liberated atoms and ions are then available for subsequent acceleration to cosmic ray energies.

This research has been supported by NASA's Astrophysics Theory Program.

444.12 – **Searching for Ejecta and Dust Formation Signatures in Young Supernova Remnants with ISO/LWS and Herschel**

Sung-Joon Park[1], J. Rho[2]

[1]*NASA Ames Research Center,* [2]*SOFIA Science Center/USRA/NASA Ames Research Center.*

9:00 AM - 2:00 PM

We report infrared detected supernova remnants (SNRs) from ISO/LWS archival data. The ionic lines and continuum of mid- to far- infrared spectroscopy using ISO/LWS were carefully examined. We have found 10-15 useful detections of infrared emission in supernova remnants. As the first project using ISO data, we identified 4 new young SNRs showing broad ionic lines. Broad ionic lines are signatures of ejecta in which dust may form. G54.1+0.3 shows broad lines of [OIII] at 88 micron, [O I] at 63 micron and [N II] at 122 micron. G320.3-1.2 (MSH15-52) shows broad lines of both [OIII] at 52 and 88 micron and [N II] at 122 micron. G21.5-0.9 and MSH11-54 show a broad line of only [N II] at 122 micron. We detect [C II] lines at 158 micron from all of the four sample SNRs, but they are not resolved within instrument resolution. We also present the archival Herschel imaging data of the four SNRs and will estimate dust masses by combing the ISO spectra and Herschel. For other ISO detected-SNRs, we plan to make ISO catalog of IR-detected SNRs.

444.13 – **Modeling Dust and Starlight in Galaxies Observed by Spitzer and Herschel: NGC 628 and NGC 6946**

Gonzalo J. Aniano Porcile[1], B. T. Draine[1], .. KINGFISH[2]

[1]*Princeton University,* [2]*..*

9:00 AM - 2:00 PM

Physical models for interstellar dust are presented for NGC 628 and NGC 6946, two well-resolved spiral galaxies observed by the IRAC and MIPS cameras on Spitzer Space Telescope, and the PACS and SPIRE cameras on Herschel Space Observatory, by the KINGFISH project. With wavelength coverage from 3.6μm to 500μm, the dust models are strongly constrained. For each pixel in each galaxy we estimate (1) the mass surface density of dust, (2) the fraction of the dust mass contributed by PAHs, (3) the distribution of intensities of starlight heating the dust grains, and (4) the IR luminosity originating in regions with high starlight intensity. The angular resolution of Herschel resolves the large scale dust structures within the galaxies. We obtain total dust masses for each galaxy by summing the dust mass over the individual map pixels. These dust masses are consistent with the masses inferred from a model fit to the global photometry. The overall dust to H mass ratio is estimated to be 0.010 ± 002 for NGC 628, and 0.012 ± 0.003 for NGC 6946, consistent with what is expected for near-solar metallicities. We do not find any evidence for significant masses of cold dust ($T < 12K$). Discrepancies between the PACS and MIPS photometry in low surface brightness areas result in large uncertainties when the modeling is done at PACS resolutions, in which case SPIRE, MIPS70μm and MIPS160μm data cannot be used, therefore we do not recommend attempting to model dust in the outer parts of the galaxies at the angular resolution of PACS. We show that, contrary to some claims, the spectral energy distribution fits are significantly improved if the starlight distribution includes a “delta function” component.

444.14 – **Dust-to-Gas Ratios in Early-type Galaxies**

Alison Faye Crocker[1], L. M. Young[2], P. Serra[3], J. Donovan Meyer[4], M. Bureau[5], Atlas3D team

[1]*University of Massachusetts Amherst,* [2]*New Mexico Tech,* [3]*ASTRON, Netherlands,* [4]*Stony Brook University,* [5]*University of Oxford, United Kingdom.*

9:00 AM - 2:00 PM

We present dust-to-gas ratios for all possible galaxies of the Atlas3D early-type galaxy sample using IRAS measurements to constrain the dust mass. Cold gas masses are combined molecular and atomic masses, determined from single-dish CO and interferometric HI measurements obtained as part of the Atlas3D survey. Many early-type galaxies exhibit high dust-to-gas ratios (above that of the Galaxy) and thus likely have a high metal-content ISM. However, a few have much lower dust-to-gas ratios, signaling the acquisition of their gas from a lower-metallicity source. Additionally, using higher-sensitivity Herschel data for 3 galaxies with outer HI distributions, we present dust-to-gas ratios for these galaxies. Two of these three galaxies have extremely low dust-to-gas ratios with only upper limits on their dust masses, despite the sensitivity of Herschel. Little dust thus exists in these outer distributions of HI, either dust destruction is rapid in these environments or the ISM is very deficient in the metals required to form dust.

444.15 – **The CO-to-H2 Conversion Factor Within GMCs in Nearby Spiral Galaxies**

Jennifer Donovan Meyer[1], J. Koda[1]

[1]*Stony Brook University.*

9:00 AM - 2:00 PM

Much of what is known about the evolution of the interstellar medium in spiral galaxies has been learned by analyzing the properties of giant molecular clouds (GMCs). However, these clouds are composed primarily of molecular hydrogen, which is difficult to observe directly since the temperature of the gas in GMCs is too low to excite H2 line emission. As a result, molecular tracers - the most common of which being the lower rotational transitions of the CO molecule - are typically observed instead, requiring a well-calibrated conversion factor between CO flux and H2 mass (Xco). To investigate GMC evolution within galactic disks, I have created high fidelity images of nearby spiral galaxies with a variety of morphologies by combining CO (J=1-0) observations from the

Nobeyama 45-meter single dish telescope and the CARMA interferometer in the uv-plane. These images, created as part of the CO Survey of Nearby Galaxies being completed at Stony Brook, utilize the new rms-weighting technique described in Koda et al. (2011).

In Donovan Meyer et al. (2011), we deconvolve the CO emission of the nearby spiral galaxy NGC 6946 into the largest sample to date of resolved GMCs in a substantial spiral galaxy other than the Milky Way and derive virial masses and Xco within individual GMCs. Extending this work to three other nearby galaxies from the survey for which we can achieve the most resolved measurements (beam sizes less than 65 pc), we find that the sizes and velocity dispersions of GMCs continue to be largely consistent from galaxy to galaxy. However, while the conversion factor remains within a factor of two compared to the Galactic value, there is an indication that it varies systematically between galaxies.

444.16 – **Estimating Interstellar Medium Dust Temperature And Spectral Index In The Far-infrared And Submillimeter**

Marcella Veneziani[1], A. Noriega-Crespo[1], F. Piacentini[2], R. Paladini[1]

[1]IPAC-Caltech, [2]University of Rome La Sapienza, Italy.

9:00 AM - 2:00 PM

Dust temperature and spectral index are evidenced to be anti-correlated from observations in the far-infrared and millimeter wavelengths and from laboratory experiments. However, uncertainties in flux measurements combined with calibration errors and other source of systematic errors, affect the results of the spectral energy distribution (SED) fit. An inverse correlation between dust temperature and spectral index naturally arises from the spectral model assumed for the fit combined with data noise and systematic uncertainties. When the spectral coverage do not sample the whole SED but only a limited range of it, it is even more difficult to get reliable results on dust physical properties. We developed a method to fit the inverse relationship between the temperature and spectral index with Bayesian statistics taking properly into account both the statistics and the systematic errors. We simulate observations of one-component Interstellar Medium (15 K < T < 25 K), and of two-components sources both warm (HII regions) and cold (cold cores) in the Herschel PACS and SPIRE spectral bands (70-500 um). We also include some ancillary simulated data from Planck-HFI, IRAS and MIPS to better sample the SEDs.

444.17 – **The Local Interstellar Magnetic Field - 100 AU to 40 pc**

Priscilla C. Frisch[1], B. Andersson[2], A. Berdyugin[3], W. DeMajistre[4], H. Funsten[5], A. M. Magalhaes[6], D. J. McComas[7], D. B. Seriacopi[8], V. Piirola[9], N. A. Schwadron[10], J. D. Slavin[11], S. J. Wiktorowicz[12]

[1]Univ. of Chicago, [2]SOFIA, USRA, [3]Finnish Center for Astronomy with ESO, U. Turku, Finland, [4]Johns Hopkins University Applied Physics Laboratory, [5]LANL, [6]Inst. de Astronomia, University de Sao Paulo, Brazil, [7]Southwest Research Institute, [8]Inst. de Astronomia, University de Sao Paulo,, Brazil, [9]Finnish Center for Astronomy with ESO, Univ. Turku, Finland, [10]Univ. of New Hampshire, [11]Harvard-Smithsonian Center for Astrophysics, [12]Dept. Astronomy, Univ. California at Santa Cruz.

9:00 AM - 2:00 PM

We present two new diagnostics of the very local interstellar magnetic field (ISMF). The Interstellar Boundary Explorer (IBEX) has discovered a 'ribbon' of energetic neutral atoms (ENAs) in the sky. This ribbon forms a nearly complete arc in the sky and coincides with sightlines that are perpendicular to the ISMF draping over, and shaping, the heliosphere. Starlight that is weakly polarized in the nearby interstellar medium provides an alternate method for obtaining the local ISMF direction over tens of parsecs. We report new results that show that the ISMF directions traced by the IBEX ribbon and polarized starlight agree, to within the uncertainties. A new technique is used to derive the ISMF direction from polarization position angles. This technique searches for the ISMF that provides the best fit to the polarization position angles of an ensemble of nearby stars, where the stars are selected to avoid intrinsic polarizations. The polarization position angles of nearby stars towards the North Polar Spur indicate that the Loop I ISMF extends to within 8 pc of the Sun. Comparisons between the ISMF derived from the IBEX ribbon, the ISMF of Loop I, and the ISMF traced by nearby pulsars in the third galactic quadrant, suggest that the "local" ISMF has the nature of an interarm field with coherent directions over relatively large scales of several hundred parsecs. The best-fitting ISMF direction from the polarization measurements supports the view that the Sun is embedded in a fragment, or filament, of a superbubble shell originating in the Sco-Cen Association, with the ISMF approximately parallel to the filament elongation.

444.18 – **IRAS 01202+6133 : A Possible Case of Protostellar Collapse Triggered by a Small HII Region**

Sung-Ju Kang[1], C. Kerton[1]

[1]Iowa State University.

9:00 AM - 2:00 PM

The molecular gas surrounding an HII region is thought to be a place where star formation can be induced. One of the main questions in the study of star formation is how protostars accrete material from their parent molecular clouds and observations of infall motions are needed to provide direct evidence for accretion. This poster will present an analysis of submm spectroscopic observations of the submm/infrared source IRAS 01202+6133 located on the periphery of the HII region KR 120. HCO+(J=3-2) spectra of this source show a classic blue-dominated double-peaked profile indicative of infall motions that would be expected to occur in the envelope surrounding a young protostellar object. The HCO+ spectrum toward the core was fitted using models incorporating both outflow and infall components along with basic assumptions regarding excitation temperature trends within molecular cloud cores. Using the models, we derive physical properties of the infall kinematics and the envelope structure.

444.19 – **Small Scale Structures as Units of Dynamical Multi-Phase Interstellar Medium**

Kengo Tachihara[1], K. Saigo[2], A. Higuchi[2], T. Inoue[3], S. Inutsuka[4]

[1]JAO/NAOJ, Chile, [2]NAOJ, Japan, [3]Aoyama Gakuin University, Japan, [4]Nagoya University, Japan.

9:00 AM - 2:00 PM

In order to investigate origin of the interstellar turbulence, detailed observations in the CO J= 1--0 and 3--2 lines have been carried out in an interacting region of a molecular cloud with a HII region. As a result, a few 1000 to 10000 AU scale cloudlets with small velocity dispersion are detected, whose systemic velocity have relatively large scatter of a few km/s. It is suggested that cloud is composed of the small-scale dense and cold structures and their overlapping effect makes cloud appearing to be turbulent entity as a whole. This picture is strongly support the two-phase model of turbulent medium driven by thermal instability proposed previously. On the surface of present cloud, the turbulence is likely to be driven by thermal instability following ionization shock compression and UV irradiation. Those small scale structures with line width of 0.6 km/s have relatively high CO line ratio of J=3--2 to 1--0 as $R_{3\text{-}2/1\text{-}0} > 1$ compared to those with 0.3 km/s line width as $R_{3\text{-}2/1\text{-}0} < 0.2$. The LVG analysis implies that the 0.6 km/s component cloudlets have peak density of at least $10^{4\text{-}6}$ cm^{-3}, more than an order of magnitude larger than those of the 0.3 km/s component, while the kinetic temperature of the 0.3 km/s component is estimated to be less than 30 K.

444.20 – **The Dust Content of Evolved HII Regions: Spitzer and Herschel Characterization**

Roberta Paladini[1]

[1]NHSC/Caltech.

9:00 AM - 2:00 PM

The recent release of high-resolution radio and NIR data of the Galactic Plane makes it possible, for the first time, to clearly distinguish the actual boundary of an HII region from the surrounding Photo-Dissociation Region (PDR). In this light, we have analyzed a uniform sample of 16 evolved HII regions located in a 20 X 20 field observed as part of the Herschel Hi-Gal survey. By combining MAGPIS 20-cm measurements with IRAC 8μm, MIPS 24μm, PACS (70μm and 160μm) and SPIRE (250μm, 350μm and 500μm) data, we have investigated the relative spatial distribution of the various populations of grains traced by these wavelengths. The analysis reveals that dust is clearly associated with the ionized gas in HII regions. In particular, the ionized gas displays a spatial distribution similar to the 24μm emission, which we tentatively interpret as due to a warm population of Big Grains (BG). At the same, we find evidence that radiation-pressure-driven drift, as proposed by Draine (2011), is the main mechanism at work in HII regions. We have also built the Spectral Energy Distributions (SEDs) for 24μm < λ 160μm appear to trace systematically the cold dust component, for which we estimate an equilibrium temperature of the Big Grains (BGs) in the range 20 - 30 K, while for λ < 70-160μm, the data corroborate the presence of a warm dust component, also due to BGs and surrounded by the cold component, at temperatures of the order of 50 - 90 K.

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445 – Milky Way Topics

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

445.01 – **Ionized Gas In The Galactic Center: New Observations, Interpretation, And Speculation**

Wesley Irons[1], J. H. Lacy[1]

[1]University of Texas.

9:00 AM - 2:00 PM

We Present new observations of the [Ne II] emission from the ionized gas in Sgr A West with improved resolution and sensitivity. About half of the emission comes from

gas with kinematics indicating it is moving on nearly circular orbits in a plane tipped about 25 degrees from the Galactic plane. This plane is consistent with that derived previously for the circumnuclear molecular disk and the northern arm and western arc ionized features. However, unlike most previous studies, we conclude that the ionized gas is not moving along the ionized features, but rather diagonally across them. The observed speeds are close to, but probably somewhat less than expected for orbital motions in the potential of the central black hole and stars. The spatial distribution of the emission is best fitted by a spiral pattern. We discuss possible physical explanations for the spatial distribution and kinematics of the ionized gas, but are unable to find a satisfactory model.

This work was supported by NSF grant AST-0607312.

445.02 – **A Search for Hydroxylamine (NH_2OH) toward Select Astronomical Sources**

Robin Pulliam[1], B. A. McGuire[2], A. J. Remijan[1]

[1]*National Radio Astronomy Observatory,* [2]*California Institute of Technology.*
9:00 AM - 2:00 PM

Observations of 14 rotational transitions of hydroxylamine (NH_2OH) using the NRAO 12 m Telescope on Kitt Peak are reported towards IRC+10216, Orion KL, Orion S, Sgr B2(N), Sgr B2(OH), W3IRS5, and W51M. Although recent models suggest the presence of NH_2OH in high abundance, these observations resulted in non-detection. Upper limits are calculated to be as much as six orders of magnitude lower than predicted by models. Possible explanations for the lower than expected abundance are explored.

445.03 – **Dust Production and the Collisional Erosion of the beta Pictoris Debris Disk**

Joseph M. Hahn[1]

[1]*Space Science Institute - Austin.*
9:00 AM - 2:00 PM

A model of a circumstellar debris disk is developed and applied to observations of the circumstellar dust orbiting beta Pictoris (Hahn 2010). This model accounts for dust production via collisions among unseen planetesimals, and grain destruction due to dust-dust collisions, with radiation pressure lofting the smaller grains out to r~1000 AU, which accounts for the disk's large spatial extent. Solving the rate equations that govern dust production and losses due to collisions then provides the dust abundance and collisional lifetime versus grain size, and the debris disk's optical depth and surface brightness versus distance from the star. Comparison to observations then yields estimates of the unseen planetesimal disk's radius, and the rate at which the disk sheds mass due to planetesimal grinding. Fitting the model to optical observations of beta Pic (Golimowski et al 2006) yields good agreement when the unseen planetesimal disk there is broad, spanning 75<r<150 AU. If it is assumed that the dust grains are bright like Saturn's icy rings (albedo Q_S=0.7), then the cross section of dust in the disk is ~$2x10^{20}$ km^2 and its mass ~10 lunar masses. In this case the planetesimal disk's dust production rate is heavy, ~10 earth-masses/Myr, implying that there is or was a substantial amount of planetesimal mass there, at least 100 earth-masses, in order to sustain the observed dust production over the system's age. But if the dust grains are darker than assumed, then the planetesimal disk's mass-loss rate and its total mass are heavier. In fact, the apparent dearth of any major planets in this region, plus the planetesimal disk's heavy mass-loss rate, suggests that the 75<r<150 AU zone at beta Pic might be a region of planetesimal destruction, rather than a site of ongoing planet formation.

445.04 – **Asymmetric Drift And Rotation Curve From RAVE And SEGUE Data**

Oleksiy Golubov[1], A. Just[1]

[1]*Astronomisches Rechen-Institut, Germany.*
9:00 AM - 2:00 PM

We use RAVE, SEGUE and Hipparcos data to study the asymmetric drift in the solar neighbourhood. We study the metallicity dependence of the asymmetric drift, discuss the reliability of the local standard of rest, and justify the asymmetric drift correction consistent with our data. SEGUE data are then used to trace the rotation curve of the Galaxy in the extended solar neighbourhood. Supplementing these data by other measurements of the rotation curve, we construct an improved mass model of the Milky Way.

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446 – Surveys & Instrumentation

Poster Session – Exhibit Hall – Thursday, January 12, 2012, 9:00 AM - 2:00 PM

446.01 – **Chandra X-ray Observatory Aimpoint and Optical Axis**

Ping Zhao[1]

[1]*Harvard-Smithsonian, CfA.*
9:00 AM - 2:00 PM

Chandra X-ray Observatory revolutionized the X-ray astronomy as being the first, and so far the only, X-ray telescope achieving sub-arcsecond resolution. The Chandra telescope is comprised of three principal elements: the High Resolution Mirror Assembly (HRMA), Pointing Control and Aspect Determination (PCAD) system, and the Science Instrument Module (SIM), which is where the X-ray detectors mounted and is connected to the HRMA by a 10-meter long Optical Bench Assembly. To achieve and retain the unprecedented imaging quality, it is critical that these three principal elements to stay rigid and stable for the entire life time of the Chandra operation. By measuring the telescope Aimpoint and Optical Axis positions on the detectors, we can exam the stability of the telescope. These positions have been monitored continuously as one of the Chandra on-orbit calibration tasks. The results show that these positions have been drifting continuously since launch. I will present the drift of the Optical Axis and Aimpoint, their default offset, and explain their impacts to the Chandra operation and evaluates the integrity and stability of the telescope. This study is essential to ensure the optimal operation of the Chandra X-ray Observatory.

446.02 – **Probing for Exoplanets Hiding in Dusty Debris Disks: Inner Disk Imaging, Characterization, and Exploration with HST/STIS Multi-Roll Coronagraphy**

Glenn Schneider[1], HST GO/12228 Team

[1]*Univ. of Arizona.*
9:00 AM - 2:00 PM

We present an overview of the EXoplanetary Circumstellar Environments and Disk Explorer (EXCEDE), selected by NASA for technology development and maturation. EXCEDE will study the formation, evolution and architectures of exoplanetary systems, and characterize circumstellar environments into stellar habitable zones. EXCEDE provides contrast-limited scattered-light detection sensitivities ~ 1000x greater than HST or JWST coronagraphs at a much smaller effective inner working angle (IWA), thus enabling the exploration and characterization of exoplanetary CS disks in currently inaccessible domains. EXCEDE will utilize a laboratory demonstrated high-performance Phase Induced Amplitude Apodized Coronagraph (PIAA-C) integrated with a 70 cm diameter unobscured aperture visible light telescope. The EXCEDE PIAA-C will deliver star-to-disk augmented image contrasts of < 10E-8 and a 1.2 lambda/D IWA of 0.14" with a wavefront control system utilizing a 64x64 element MEMS DM and fast steering mirror. EXCEDE will provide 144 mas spatial resolution at 0.4 microns with dust detection sensitivity to levels of a few tens of zodis with two-band imaging polarimetry. EXCEDE is a science-driven technology pathfinder that will advance our understanding of the formation and evolution of exoplanetary systems, placing our solar system in broader astrophysical context, and will demonstrate the high contrast technologies required for larger-scale follow-on and multi-wavelength investigations on the road to finding and characterizing exo-Earths in the years ahead.

446.03 – **Flight Demonstration of a Milli-Arcsecond Optical Pointing System for Direct Exoplanet Imaging**

Christopher Mendillo[1], S. Chakrabarti[1], T. Cook[1], B. Hicks[1]

[1]*Boston University.*
9:00 AM - 2:00 PM

The PICTURE (Planetary Imaging Concept Testbed Using a Rocket Experiment) sounding rocket attempted to use a white-light nulling interferometer to image the exozodiacal dust disk of Epsilon Eridani (K2V, 3.22 pc) in reflected visible light down to an inner radius of 3 AU. PICTURE launched from White Sands Missile Range on October 8th, 2011. Unfortunately, the main science telemetry channel was lost seconds into flight and no science data was recovered. However, on-board diagnostic data does show that PICTURE successfully demonstrated a fast (200 Hz) optical tracking system that provided ~2 milli-arcsecond in-flight pointing stability, a thousand-fold improvement over the raw pointing of the rocket's attitude control system (ACS). The PICTURE flight provides heritage for a technology that will be a key component for many future direct exoplanet imaging missions.

We present a spectral analysis of the 200 Hz tracking data in comparison to the 50 Hz ACS gyro data and we provide a precise measurement of the true ACS performance at frequencies higher than 5 Hz where the ACS gyros become noise limited. This work is funded by NASA grant: NNG05WC17G.

446.04 – **ACIS Focal Plane Temperature Control and Observational Strategies**

Nancy Adams-Wolk[1], P. P. Plucinsky[1], T. L. Aldcroft[1], G. Germain[1]

[1]*Harvard-Smithsonian, CfA.*
9:00 AM - 2:00 PM

The Chandra X-Ray Observatory continues to deliver excellent science to the astronomical community as it enters its 13th observation cycle. The thermal conditions of the spacecraft components have changed over time necessitating changes in observing strategies; particularly for the ACIS Instrument.

In this poster, we focus on the thermal conditions that affect the ACIS focal plane

temperature, and the ACIS observational parameters that need to be carefully considered for the observer. We discuss the electronics affected, the specific conditions that can effect the science return and how Guest Observers can choose observational parameters to mitigate these issues.The Guest Observers must be aware of changes and considerations needed when preparing their observations to continue the high quality of science return from Chandra.

446.05 – **Common-resolution Convolution Kernels For Space- And Ground-based Telescopes**

Gonzalo J. Aniano Porcile[1], B. T. Draine[1], K. D. Gordon[2], K. Sandstrom[3]

[1]Princeton University, [2]SpaceTelescope Science Institute, [3]Max-Planck Institut fur Astronomie, Germany.

9:00 AM - 2:00 PM

Multiwavelength study of extended astronomical objects requires combining images from instruments with differing point-spread functions (PSFs). We describe the construction of convolution kernels that allow one to generate (multiwavelength) images with a common PSF, thus preserving the colors of the astronomical sources. We generate convolution kernels for the cameras of the Spitzer Space Telescope, Herschel Space Observatory, Galaxy Evolution Explorer (GALEX), Wide-field Infrared Survey Explorer (WISE), ground-based optical telescopes (Moffat functions and sum of Gaussians), and Gaussian PSFs. Kernels for other telescopes including IRAS, AKARI, and Planck, are currently being constructed. These kernels allow the study of the spectral energy distribution (SED) of extended objects, preserving the characteristic SED in each pixel. The convolution kernels and the IDL packages used to construct and use them are made publicly available.

446.06 – **AEGIS: An Astrophysics Experiment for Grating and Imaging Spectroscopy---a Soft X-ray, High-resolution Spectrometer**

David Huenemoerder[1], M. W. Bautz[1], J. E. Davis[1], R. K. Heilmann[1], J. C. Houck[1], H. L. Marshall[1], J. Neilsen[1], F. Nicastro[2], M. A. Nowak[1], M. L. Schattenburg[1], N. S. Schulz[1], R. K. Smith[2], S. Wolk[2], AEGIS Team

[1]MIT Kavli Institute, [2]SAO.

9:00 AM - 2:00 PM

AEGIS is a concept for a high-resolution soft X-ray spectroscopic observatory developed in response to NASA's request for definitions of the next X-ray astronomy mission. At a small fraction of the cost of the once-planned International X-ray Observatory (IXO), AEGIS has capabilities that surpass IXO grating spectrometer requirements, and which are far superior to those of existing soft X-ray spectrometers. AEGIS incorporates innovative technology in X-ray optics, diffraction gratings and detectors. The mirror uses high area-to-mass ratio segmented glass architecture developed for IXO, but with smaller aperture and larger graze angles optimized for high-throughput grating spectroscopy with low mass and cost. The unique Critical Angle Transmission gratings combine low mass and relaxed figure and alignment tolerances of Chandra transmission gratings but with high diffraction efficiency and resolving power of blazed reflection gratings. With more than an order of magnitude better performance over Chandra and XMM grating spectrometers, AEGIS can obtain high quality spectra of bright AGN in a few hours rather than 10 days. Such high resolving power allows detailed kinematic studies of galactic outflows, hot gas in galactic haloes, and stellar accretion flows. Absorption line spectroscopy will be used to study large scale structure, cosmic feedback, and growth of black holes in thousands of sources to great distances. AEGIS will enable powerful multi-wavelength investigations, for example with Hubble/COS in the UV to characterize the intergalactic medium. AEGIS will be the first observatory with sufficient resolution below 1 keV to resolve thermally-broadened lines in hot (~10 MK) plasmas. Here we describe key science investigations enable by Aegis, its scientific payload and mission plan.

Acknowledgements: Support was provided in part by: NASA SAO contract SV3-73016 to MIT for the Chandra X-ray Center and Science Instruments; NASA grant NNX08AI62G; and the MKI Instrumentation Development Fund.

446.07 – **InFOCμS: A Balloon Instrument with <10 Arc Second Hard X-ray Imaging**

Jack Tueller[1], W. Zhang[1], S. D. Barthelmy[1], A. Furuzawa[2], Y. Haba[2], H. Krimm[3], H. Kunieda[2], T. Okajima[1], T. Miyazawa[2], R. F. Mushotzky[4], K. Tamura[2], Y. Tawara[2]

[1]NASA/GSFC, [2]Nagoya University, Japan, [3]CRESST/USRA/GSFC, [4]University of Maryland, College Park.

9:00 AM - 2:00 PM

The International Focusing Optics Collaboration for μCrab Sensitivity (InFOCμS) is currently funded to develop a balloon payload with a multilayer hard X-ray telescope based on slumped glass technology similar to NuSTAR, but with spatial resolution 40 times smaller PSF area than NuSTAR). The key science goal for this technology is a deep hard X-ray survey to understand role of AGN/black holes in the formation of galaxies. Due to obscuration, this can only be achieved in the hard X-ray band, where absorption is insignificant, and that only hard X-ray measurements can unambiguously determine the luminosities of individual AGN. InFOCμS will demonstrate the technology necessary to resolve the cosmic hard X-ray background and bridge the gap between NuSTAR, which can only resolve 45-65% of the background due to source confusion, and Chandra, which can detect all of the absorbed sources only at $z>2$. A hard X-ray survey with high spatial resolution would be a direct measurement of the luminosity function of AGN near the peak of their activity at $z=0.8$. We will present our approach to achieve high spatial resolution hard X-ray imaging at a cost that can be demonstrated in a balloon instrument with a resolved image of the Crab Nebula, and can be scaled to a deep-survey Explorer mission. This requires extensive refinement of the glass mirror technology at small increase in cost, higher spatial resolution focal plane detectors, and the use of techniques to achieve the extremely low background necessary for very long integration times required for a deep survey. The balloon payload will require significant improvements in pointing stability and knowledge over previous high-energy instruments to utilize the imaging capability of this telescope. InFOCμS is being prepared for a flight in the fall of 2013.

446.08 – **MUSTANG2: High-resolution SZE Imaging Of Galaxy Clusters With The GBT**

Alexander Young[1], J. Aguirre[1], M. Devlin[1], S. Dicker[1], P. Korngut[2], B. Mason[3], T. Mroczkowski[2], E. Reese[1], C. Romero[3], M. Rosenman[1], C. Sarazin[3], J. Sievers[4], M. Sun[3]

[1]University of Pennsylvania, [2]Caltech, [3]University of Virginia, [4]Princeton University.

9:00 AM - 2:00 PM

We present the next generation of the MUltiplexed SQUID/TES Array at Ninety GHz (MUSTANG2), a proposed 208-pixel feedhorn-coupled bolometer array for the 100m Green Bank Telescope. Utilizing the Sunyaev-Zel'dovich Effect (SZE) at 90 GHz, MUSTANG2 will produce high-resolution (9") images of the intra-cluster medium (ICM) in galaxy clusters, the largest gravitationally bound objects in the Universe. The SZE is a redshift-independent, complementary probe of the ICM to X-ray emission which diminishes with redshift and varies as the square of density. In deep (1 hour) observations MUSTANG2 can measure pressure profiles of high mass clusters out to and beyond the virial radius and down to substructure in the cluster core. In 15 hour observations, MUSTANG2 can do the same for low mass ($M=7x10^{13}M_{solar}$) systems at $z>.35$. This is nearly a decade in mass below the current limits of SZE instruments such as ACT, SPT, and *Planck*. This broad angular and dynamic range is important for studying the low normalization to the cluster power spectrum found recently by ACT and SPT as well as the contribution of cluster outskirts to the integrated SZE flux.

SZE surveys have the potential to place tight constraints on cosmological parameters with cluster number counts but rely on accurate determination of the scaling between integrated SZE flux and cluster mass. Current SZE survey instruments cannot resolve features due to mergers and AGN feedback, which could introduce scatter and bias the SZE cluster selection function. MUSTANG2, however, *can* resolve these features and determine the extent to which the scaling relations have been biased by cluster astrophysical phenomena. With unprecedented sensitivity, nearly 25 times that of the current MUSTANG receiver, MUSTANG2 will map hundreds of clusters per season, which will unlock the full potential of galaxy clusters as cosmological probes.

446.09 – **State of Detector Development for the WIYN One Degree Imager: Deploying a Partially Populated Focal Plane in Summer 2012**

Daniel R. Harbeck[1], T. Boroson[2], M. Lesser[3]

[1]WIYN Observatory, [2]National Optical Astronomy Observatory, [3]UA Imaging Technology Laboratory.

9:00 AM - 2:00 PM

The deployment of the WIYN One Degree Imager (ODI) was delayed due to issues with the production of its Orthogonal Transfer Array (OTA) detectors. OTA detectors allow moving charge in the detector area during an ongoing science integration to compensate for image motion caused by either telescope guide errors or atmospheric turbulence. In 2011 a small experimental foundry run with a modified design has yielded at least 14 devices that meet science requirements for conventional static imaging mode. Active correction of telescope guide errors by the detectors will be achievable with some precautions during operation, whereas atmospheric motion correction will remain limited to a technical demonstration due to persistent amplifier glow.

In this poster we describe the characteristics of these devices and present a plan for the deployment of ODI with a partially populated focal plane (pODI) at the WIYN telescope in the second half of 2012. pODI will be used to characterize the performance of the ODI instrument and will be used for science operations while the future development options for OTA detectors are considered.

446.10 – **VEGAS: VErsatile GBT Astronomical Spectrometer**

Srikanth Bussa[1], VEGAS Development Team

[1]National Radio Astronomy Observatory.

9:00 AM - 2:00 PM

The National Science Foundation Advanced Technologies and Instrumentation (NSF-ATI) program is funding a new spectrometer backend for the Green Bank

Telescope (GBT). This spectrometer is being built by the CICADA collaboration - collaboration between the National Radio Astronomy Observatory (NRAO) and the Center for Astronomy Signal Processing and Electronics Research (CASPER) at the University of California Berkeley.The backend is named as VErsatile GBT Astronomical Spectrometer (VEGAS) and will replace the capabilities of the existing spectrometers. This backend supports data processing from focal plane array systems. The spectrometer will be capable of processing up to 1.25 GHz bandwidth from 8 dual polarized beams or a bandwidth up to 10 GHz from a dual polarized beam.The spectrometer will be using 8-bit analog to digital converters (ADC), which gives a better dynamic range than existing GBT spectrometers. There will be 8 tunable digital sub-bands within the 1.25 GHz bandwidth, which will enhance the capability of simultaneous observation of multiple spectral transitions. The maximum spectral dump rate to disk will be about 0.5 msec. The vastly enhanced backend capabilities will support several science projects with the GBT. The projects include mapping temperature and density structure of molecular clouds; searches for organic molecules in the interstellar medium; determination of the fundamental constants of our evolving Universe; red-shifted spectral features from galaxies across cosmic time and survey for pulsars in the extreme gravitational environment of the Galactic Center.

446.11 – **CQUEAN: New CCD Camera System For The Otto Struve Telescope At The McDonald Observatory**

Soojong Pak[1], W. Park[2], M. Im[2]

[1]Kyung Hee Univ., Korea, Republic of, [2]Seoul National University, Korea, Republic of.
9:00 AM - 2:00 PM

We describe the overall characteristics and the performance of an optical CCD camera system, Camera for QUasars in EArly uNiverse (CQUEAN), which is being used at the 2.1m Otto Struve Telescope of the McDonald Observatory since 2010 August. CQUEAN was developed for follow-up imaging observations of near infrared bright sources such as high redshift quasar candidates ($z > 4.5$), Gamma Ray Bursts, brown dwarfs, and young stellar objects. For efficient observations of the red objects, CQUEAN has a science camera with a deep depletion CCD chip. By employing an auto-guiding system and a focal reducer to enhance the field of view at the classic cassegrain focus, we achieved a stable guiding in 20 minute exposures, an imaging quality with FWHM > 0.6 arcsec over the whole field (4.8 × 4.8 arcmin), and a limiting magnitude of $z = 23.4$ AB mag at 5-sigma with one hour integration.

446.12 – **Design Of And Progress Towards The Gravity Wave-front Sensors**

Casey Deen[1], W. Brandner[1], S. Hippler[1], R. Lenzen[1], V. Naranjo[1], R. Rohloff[1], W. Laun[1], R. Klein[1], J. R. Ramos[1], U. Neumann[1], A. Böhm[1], A. Huber[1], S. Kendrew[1], P. Yang[1], N. Kudryavtseva[1], Y. Clénet[2], E. Gendron[2]

[1]Max Planck Institute for Astronomy, Germany, [2]l'Observatorie de Paris, France.
9:00 AM - 2:00 PM

The GRAVITY instrument is a beam-combining interferometer for the four telescopes of the VLT, and relies upon four near-infrared (1.4-2.4 micron) Shack-Hartmann style wave-front sensors to determine the atmospheric distortion due to atmospheric turbulence. The GRAVITY AO system will then drive the VLT's MACAO deformable mirrors to correct the wavefront, permiting 10 micro-arcsecond astrometry. We present the current design and status of the wave front sensor system, as well as future plans for integration and test.

446.13 – **VISION: The Next Generation Science Camera for the Navy Optical Interferometer**

Askari Ghasempour[1], M. Muterspaugh[1], D. Hutter[2], J. Monnier[3], T. Armstrong[4], J. Benson[2], D. Mozurkewich[5], M. Williamson[1], S. Fall[1], C. Harrison[1], C. Sergeyous[1]

[1]Tennesee State University, [2]US Naval Observatory, [3]University of Michigan, [4]Naval Research Laboratory, [5]Seabrook Engineering.
9:00 AM - 2:00 PM

The Visible Imaging System for Interferometric Observations at NOI (VISION) will be a versatile camera for high resolution astronomical imaging. It allows precision measurements at the Navy Optical Interferometer (NOI), with spatial resolution 200 times sharper than what is possible with the Hubble Space Telescope while furthering technological capabilities. This resolution allows one to reconstruct multipixel images of stars. VISION is a fiber-optics based beam combiner that can coherently combine up to six telescope beams using a spatially-modulated image-plane combination scheme. In comparison to NOI's current beam combiner, VISION is able to achieve a higher precision result and a better flexibility by incorporating single mode fibers for spatial filtering that removes the effect of atmospheric turbulence and also by using low-noise detectors.

The VISION project was initiated in June 2010. The team completed the optical design and system requirement studies, including simulations and tradeoff studies, for the fiber feed system and fringe forming optical system in the first step. Purchasing and installation of the mechanical and optical components including camera, spectrograph, optical table, and optical fibers were completed in December 2010. The current status of VISION is that the first throughput test of the fiber feed unit at NOI confirmed adequate throughput of the system. The control software for the camera, spectrograph, and fiber micro-positioners were developed. High quality laser fringes and first white light fringes were demonstrated in the Tennessee State University laboratory. The full system is expected to be delivered in early 2012.

446.14 – **RIMAS - Optical Design Development of the Imager/Spectrometer for the Discovery Channel Telescope**

John Capone[1], D. Content[2], A. Kutyrev[3], S. Veilleux[1], S. Moseley[1], N. Gehrels[2]

[1]The University of Maryland, [2]GSFC, [3]GSFC / The University of Maryland.
9:00 AM - 2:00 PM

The Rapid IMAger - Spectrometer (RIMAS) is a collaborative effort between the University of Maryland at College Park, NASA-GSFC and Lowell Observatory designed for use on the 4.3 meter Discovery Channel Telescope at Lowell. The primary science goal of the instrument is the study of gamma-ray burst (GRB) afterglow appearing in the near-infrared. Continuous operation will allow measurements beginning minutes after the prompt emission. We present the results of the RIMAS optical design development. The instrument consists of two arms separated by a dichroic: the first for the Y and J bands (0.9 - 1.35 microns) and the second for the H and K-bands (1.5 - 1.8 and 2.0 - 2.4 microns). Each arm will be equipped with two broad band filters for imaging, as well as low resolution and echelle grisms. The imaging modes are designed to be diffraction limited, with one pixel corresponding to ~0.35 arcseconds, while the diffractive modes have resolving powers of approximately 20 and 4,000. With photometric and spectroscopic capabilities, RIMAS will be well positioned to quickly determine redshifts, followed by high resolution spectroscopic studies of GRB afterglow.

446.15 – **Radio Transient Searches using Low Frequency VLA Archival Observations**

Theodore Jaeger[1], N. Kassim[1], S. Hyman[2], J. Lazio[3], R. Osten[4], R. Mutel[5], W. Peters[1]

[1]US Naval Research Laboratory, [2]Department of Physics and Engineering - Sweet Briar College, [3]Jet Propulsion Laboratory, [4]Space Telescope Science institure, [5]Department of Physics and Astronomy - The University of Iowa.
9:00 AM - 2:00 PM

A variety of sources are predicted to emit at meter wavelengths and would likely appear as transients. This source list includes extrasolar planets, brown dwarfs, and prompt emission from gamma ray bursts. Low frequency VLA observations are well suited to probe the dynamic radio sky, given the the large field of view (> 150 deg^2) at 74 MHz and sub-mJy sensitivity at 325 MHz. We present results from various low frequency radio transient searches using data from the VLA archive, a rich reservoir of largely unsearched data. In particular, we report on multiple 325 MHz searches using targeted fields and an all-sky search using fields from the 74 MHz VLA Low frequency Sky Survey (VLSS). The VLSS variability and transient emission search is the largest to date, covering over 3 pi steradians with minute to multi-year flux measurements of 50,000 field sources.

446.16 – **Lightcurve Based Classification Of Transients Events**

Ciro Donalek[1], M. J. Graham[1], A. Mahabal[1], S. G. Djorgovski[1], A. J. Drake[1], B. Moghaddam[2], M. Turmon[2], Y. Chen[1], N. Sharma[1]

[1]Caltech, [2]JPL.
9:00 AM - 2:00 PM

In many scientific fields, a new generation of instruments is generating exponentially growing data streams, that may enable significant new discoveries. The requirement to perform the analysis rapidly and objectively, coupled with the huge amount of data available, implies a need for an automated event detection, classification, and decision making. In astronomy, this is the case with the new generation of synoptic sky surveys, that discover an ever increasing number of transient events. However, not all of them are equally interesting and worthy of a follow-up with limited resources. This presents some unusual classification challenges: the data are sparse, heterogeneous and incomplete; evolving in time; and most of the relevant information comes from a variety of archival data and contextual information. We are exploring a variety of machine learning techniques, using the ongoing CRTS sky survey as a testbed: Bayesian Network, [dm,dt] histograms, Decision Trees, Neural Networks, Symbolic Regression. In this work we focus on the lightcurve based classification using an hierarchical approach where some astrophysically motivated major features are used to separate different groups of classes. Proceeding down the classification hierarchy every node uses those classifiers that are demonstrated to work best for that particular task.

446.17 – **The C-Band All-Sky Survey: Northern Survey Progress and Southern Survey Instrument**

Oliver G. King[1], C-BASS Team

[1]California Institute of Technology.
9:00 AM - 2:00 PM

The C-Band All-Sky Survey (C-BASS) is a project that aims to produce sensitive, all-sky maps of Galactic synchrotron emission at 5 GHz in total intensity and linear polarization. These measurements will be used primarily in the subtraction of foregrounds from measurements of the polarized Cosmic Microwave Background. Secondary scientific goals include studying the nature of the Galactic magnetic field, constraining the Galactic cosmic ray energy spectrum, and constraining low frequency foregrounds including anomalous microwave emission. Measurements will be performed using a 6 m dish at the Owens Valley Radio Observatory (OVRO) in California, and a 7 m dish in the new Radio Astronomy Park near Carnarvon, South Africa. The Northern hemisphere observations are underway, the Southern instrument is complete, and deployment of the Southern receiver is planned for early 2012. We discuss the progress of the survey observations, present a preview of the Northern hemisphere data, and discuss the performance of the instrument.

The C-BASS project is a collaboration between Caltech/JPL in the US, Oxford and Manchester Universities in the UK, KACST in Saudi Arabia, and Rhodes University and the Hartebeesthoek Radio Astronomy Observatory in South Africa. It is funded by the NSF (AST-0607857) and the participating institutions.

http://www.astro.caltech.edu/cbass/

446.18 – **The Search for Possible Stellar Companions of DEBRIS Candidate Stars: An Update**

Harold M. Butner[1], A. Saikin[1], G. S. Leisure[1], C. A. Wolfe[1], H. Tom[2], G. Duchene[2], D. Rodriguez[3], DEBRIS Team

[1]*James Madison Univ.,* [2]*UC Berkeley,* [3]*U. Chile, Chile.*

9:00 AM - 2:00 PM

Among the key projects of the ESO Herschel mission is a survey that searches for evidence of associated debris disks among nearby main sequence stars. The DEBRIS sample covers nearly 450 stars ranging from spectral type A0 through late M-stars. To model properly the far-infrared results, it is important to know whether the candidate stars have companions or not. To this end, we have undertaken a survey of nearly 300 of the DEBRIS stars that are visible from the northern hemisphere using the Shane 3-meter telescope at Lick Observatory. Our observations are done in the J, H, and K bands with the Shane adaptive optics system and the Lick Observatory IRCAL (a near-infrared IR camera). These observations allow us to look for previously undetected companions in the DEBRIS sample, down to possible separations as small as a few AU between the primary and companion. We present our current results for nearly 200 stars and discuss future planned observations.

446.19 – **The Spitzer Extragalactic Representative Volume Survey (SERVS)**

Jean-Christophe Mauduit[1], M. Lacy[2], D. Farrah[3], J. Surace[1], M. Jarvis[4], S. Oliver[3], C. Maraston[5], SERVS team

[1]*California Institute of Technology,* [2]*National Radio Astronomy Observatory,* [3]*University of Sussex, United Kingdom,* [4]*University of Hertfordshire, United Kingdom,* [5]*University of Portsmouth, United Kingdom.*

9:00 AM - 2:00 PM

We present details of the *Spitzer Extragalactic Representative Volume Survey* (SERVS), an 18 square degrees medium-deep survey at 3.6 and 4.5 μm with the post-cryogenic *Spitzer Space Telescope* to ≈ 2 μJy (AB=23.1) depth of five highly observed astronomical fields (Elais-N1, Elais-S1, Lockman Hole, Chandra-Deep Fied South and XMM). Data will be made available to the community in the Spring of 2012. SERVS is designed to enable the study of galaxy evolution as a function of environment from $z \approx 5$ to the present day, and is the first extragalactic survey both large enough and deep enough to put rare objects such as luminous quasars and galaxy clusters at $z \geq 1$ into their cosmological context. SERVS is designed to overlap with several key surveys at optical, near- through far-infrared, submillimeter and radio wavelengths to provide a coherent picture of the formation of massive galaxies.

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401 – The Wide-Field Infrared Survey Explorer (WISE): Science Frontiers and Final Data Release

Special Session – Room 17B – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

The Wide-field Infrared Survey Explorer (WISE), a medium class Explorer NASAmission, was launched on 14 Dec 2009 and mapped the entire sky at 3.4, 4.6, 12, and22 microns with 5 sigma point source sensitivities of approximately 0.05, 0.1, 0.73, and5.9 mJy or better in the four bands, respectively. WISE detected hundreds of millionsof stars and galaxies, including millions of ULIRGS and QSOs, hundreds of thousandsof asteroids, and hundreds of brown dwarfs. Preliminary WISE data products consistingof a Source Catalog, Image Atlas, and Explanatory Supplement were released in April2011 and covered 57% of the sky. The final data release, with full-sky coverage, isplanned in March 2012. Several illustrative WISE science results will be presented inthis session to suggest how the WISE survey and complementary measurements canyield groundbreaking results. The session will also include an overview of the WISEdata products and mention an imminent opportunity to obtain funding support for WISE-related data analysis through NASA's Astrophysics Data Analysis Program.

401.01 – **WISE Enables the Community's Science**

Edward L. Wright[1]

[1]*UC, Los Angeles.*

10:00 AM - 10:13 AM

The Wide-field Infrared Survey Explorer (WISE) surveyed the whole sky between 14 Jan 2010 and 5 August 2010 in 4 infrared bands centered at 3.4, 4.6, 12 and 22 microns. The talks in this session will highlight WISE science team results. But on 14 April 2011 WISE made a preliminary data release (PDR) covering 57% of the sky which has already led to several published results from outside the WISE team. The single frame images and source extraction database have been used to study RR Lyra stars and a flaring X-ray binary, which both have variations in the 1-2 day typical WISE coverage span. Followup of NEOs found by WISE have led to well-publicized objects in resonance with the Earth: one in a horseshoe orbit and one a Trojan librating about the Earth-Sun L4 point. The coadded image atlas and catalog have been used to find high proper motion stars including several late Ts dwarf and a nearby L dwarf in the Kepler field. I expect many more groups will find gems hidden in the WISE PDR and especially in the WISE final data release scheduled for 2012.

401.02 – **A WISE Look at Near Earth Objects**

A. Mainzer[1], J. Bauer[1], T. Grav[2], J. Masiero[1], R. S. McMillan[3], R. Walker[4], E. L. Wright[5], R. M. Cutri[6], D. J. Tholen[7], WISE/NEOWISE Teams

[1]*JPL,* [2]*Planetary Science Institute,* [3]*University of Arizona,* [4]*MIRA,* [5]*UCLA,* [6]*Infrared Processing and Analysis Center, Caltech,* [7]*University of Hawaii.*

10:15 AM - 10:28 AM

With the Wide-field Infrared Survey Explorer's project for solar system exploration (known as NEOWISE), we have observed more than 157,000 asteroids and comets in wavelengths ranging from 3 - 22 microns. This number includes the discovery of more than 33,000 new asteroids, mostly in the Main Belt. NEOWISE detected more than 500 near-Earth objects (NEOs) and 135 comets, including the discovery of 135 new NEOs and 21 new comets. The NEOWISE project detected moving objects in a highly uniform fashion with well-known survey biases, allowing predictions of the numbers, sizes, and albedos to be made for various populations with greater precision than previous estimates. We have made an estimate of the numbers, sizes and albedos of the near-Earth asteroids, yielding the means to obtain an improved understanding of both the hazard they pose to the Earth as well as their origins and evolution. Similar analyses can be applied to other asteroid populations throughout the solar system, including the Main Belt, Jovian Trojans, and Hildas. Current results from the NEOWISE project will be summarized.

401.03 – **The Discovery of Y Dwarfs with WISE**

Michael Cushing[1]

[1]*University of Toledo.*

10:30 AM - 10:43 AM

One of the primary science goals of the Wide-field Infrared Survey Explorer (WISE), a NASA mission that surveyed the sky at four mid-infrared wavelengths, is to identify very cold (Teff < 600 K) brown dwarfs. With atmospheric conditions similar to that of giant planets, brown dwarfs are ideal exoplanet analogs that can be observed free from the contaminating light of host stars. The study of these cold brown dwarfs will also provide constraints on the functional form of the low-mass mass function and on the lower mass limit of star formation, two critical constraints on theories of star formation. To date, we have identified roughly one hundred new brown dwarfs with WISE, six of which are so cold (Teff < 500 K) that the creation of a new spectral class, dubbed 'Y', was required. I will discuss the discovery of the Y dwarfs as well as our modeling effort aimed at deriving their atmospheres parameters using the model atmospheres of Marley and Saumon. The continued study of such ultracool brown dwarfs will directly inform the interpretation and characterization of exoplanets discovered with the next generation of high-contrast imagers like GPI and SPHERE.

401.04 – **A WISE Look at Debris Disks**

Deborah Padgett[1]

[1]*NASA's GSFC.*

10:45 AM - 10:58 AM

The Wide Field Infrared Survey Explorer (WISE) has just completed a sensitive all-sky survey in photometric bands at 3.4, 4.6, 12, and 22 microns. We report on a preliminary investigation of main sequence Hipparcos and Tycho catalog stars with 22 micron emission in excess of photospheric levels. This warm excess emission traces material in the circumstellar region likely to host terrestrial planets and is preferentially found in young systems with ages < 1 Gyr. Nearly a hundred new warm debris disk candidates are detected among FGK stars, and 150 are found for A stars within 120 pc. We are in the process of obtaining spectra to determine spectral types and activity level of these stars and are using HST, Herschel and Keck to characterize the dust, multiplicity, and substellar companions of these systems. In this contribution, we will discuss source selection methods and individual examples from among the WISE debris disk candidates.

401.05 – **The Reddest Extragalactic WISE Sources: Hot DOGs?**

Peter R. Eisenhardt[1]

[1]*JPL.*

11:00 AM - 11:13 AM

One of the two primary science objectives for NASA's Wide-field Infrared Survey Explorer (WISE) is to identify the most luminous galaxies in the Universe. We have used WISE photometry to select an all-sky sample of ~1,000 objects which are extremely luminous. The sources are prominent at 12 microns (W3) or 22 microns (W4), but faint or undetected at 3.4 microns (W1) and 4.7 microns (W2), and hence referred to as "W12drops." I will provide an overview of several programs to follow up the objects. Observations of the full sample with Spitzer are largely complete, confirming that W12drops are redder than previously identified populations. Spectroscopy of ~100 W12drops shows that the majority have z > 1.6. Herschel PACS and SPIRE photometry for a subsample of 91 is underway, and sub-millimeter and millimeter data have been obtained for approximately a dozen sources. These reveal SEDs that tend to peak below rest frame 100 microns, so that hot dust dominates the bolometric luminosity, which can exceed 100 trillion solar luminosities. Optical and near-IR imaging programs, including adaptive optics and HST, are in progress. These will address whether lensing is a major factor in the population. Modeling of one W12drop suggests the luminous AGN phase may precede galaxy formation, contrary to prevailing ideas. We suggest these hot, dust-obscured galaxies, or hot DOGs, represent a rare transitional stage in the interplay between the formation of galaxy bulges and super-massive black holes.

401.06 – **WISE Final Data Release Preview**

Roc M. Cutri[1], IPAC/WISE Science Data Center Team

[1]*Caltech, IPAC.*

11:15 AM - 11:28 AM

The Wide-Field Infrared Survey Explorer (WISE) is a NASA Medium Class Explorer Mission that conducted a digital, imaging survey of the entire sky in the 3.4, 4.6, 12 and 22 micron bands in 2010. The WISE Final Data Release is scheduled for the Spring of 2012, and will be comprised of an Atlas of 18,240 coadded 1.56x1.56 degree image sets covering the sky, and an all-sky Source Catalog containing accurate positions and fluxes in the four WISE bands for several hundred million objects detected on the Atlas Images. The Final Release will include several ancillary products including over 1.5 million sets of WISE single-exposure images and a Working Database of more than 9 billion source extractions made from those images.

The Infrared Processing and Analysis Center, California Institute of Technology is the WISE Science Data Center (WSDC) and is responsible for processing, archiving and distribution of WISE science data products. We will describe the general properties, characteristics and Atlas and Catalog formats of the WISE Final Release Data Products, and how those data can be accessed by the user community via the on-line services of the NASA/IPAC Infrared Science Archive.

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402 – Large Scale Structure

Oral Session – Ballroom G – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

402.01 – **The 6dF Galaxy Survey: Baryon Acoustic Oscillations and the Local Hubble Constant**

Florian Beutler[1], C. Blake[2], M. Colless[3], L. Staveley-Smith[1], H. Jones[4]

[1]*ICRAR, Australia,* [2]*Swinburne University, Australia,* [3]*AAO, Australia,* [4]*Monash University, Australia.*

10:00 AM - 10:10 AM

The large-scale correlation function of the 6dF Galaxy Survey (6dFGS) allows the detection of a Baryon Acoustic Oscillation (BAO) signal. The low effective redshift of 6dFGS makes it a competitive and independent alternative to Cepheids and low-z supernovae in constraining the Hubble constant. It also depends on very different (and arguably smaller) systematic uncertainties. We found a Hubble constant of $H_0 = 67$ +/- 3.2 km/s/Mpc in agreement with the current standard cosmological model LCDM.

402.02 – **Acoustic Scale from the Angular Power Spectra of SDSS DR8 Photometric LRGs**

Hee-Jong Seo[1], S. Ho[2], M. White[1], A. Cuesta[3], A. Ross[4], S. Saito[1], B. Reid[2], N. Padmanabhan[3], W. Percival[4], R. de Putter[5], D. Schlegel[2], D. J. Eisenstein[6], L. A. N. da Costa[7], F. Prada[8], B. Ramos[9], F. de Simoni[9], R. Skibba[10], L. Verde[11], J. R. Gott, III[12], I. Zehavi[13]

[1]*University of California, Berkeley,* [2]*LBL,* [3]*Yale University,* [4]*University of Portsmouth, United Kingdom,* [5]*IFIC, Universidad de Valencia-CSIC, Spain,* [6]*Havard University,* [7]*Laborat´orio Interinstitucional de e-Astronomia- LineA, Brazil,* [8]*Instituto de Astrofisica de Andalucia (CSIC), Spain,* [9]*Observato´rio Nacional, Rua Gal, Brazil,* [10]*Steward Observatory, University of Arizona,* [11]*nstitut de Ciencies del Cosmos, ICC-UB, Spain,* [12]*Princeton University,* [13]*Case Western Reserve University.*

10:10 AM - 10:20 AM

We measure the acoustic scale from the angular power spectra of the SDSS III DR8 imaging catalog that includes 872,921 galaxies

over ~ 10,000 deg^2 between $0.45<z<0.65$. The extensive spectroscopic training set of SDSS III BOSS LRGs allows precise estimates of the true redshift distributions of galaxies in our imaging catalog. Utilizing the redshift distribution information, we build templates and fit to the measured power spectra to derive the BAO scale while marginalizing over enough free parameters to exclude nearly all of the non-BAO information. We derive the ratio of the angular diameter distance to the sound horizon scale DA/rs= 9.212+0.416-0.404 at z=0.54, and therefore, DA= 1411+- 65 Mpc at z=0.54; the result is fairly independent of assumptions on the underlying cosmology. Our measurement of angular diameter distance DA is 1.4 sigma higher than what is expected for the concordance LCDM (Komatsu et al. 2011), in accordance to the trend of other spectroscopic BAO measurements for $z >\sim 0.35$. We report constraints on cosmological parameters from our measurement in combination with the WMAP7 data and the previous spectroscopic BAO measurements of SDSS (Percival et al. 2010) and WiggleZ (Blake et al. 2011).

402.03 – **Testing Gravity and Cosmic Acceleration with Galaxy Clustering**

Eyal Kazin[1], J. Tinker[2], A. G. Sanchez[3], M. Blanton[2]

[1]*Swinburne University of Technology, Australia,* [2]*New York University,* [3]*Max Planck Institut fur Extraterrestische Physik, Germany.*

10:20 AM - 10:30 AM

The large-scale structure contains vast amounts of cosmological information that can help understand the accelerating nature of the Universe and test gravity on large scales. Ongoing and future sky surveys are designed to test these using various techniques applied on clustering measurements of galaxies.

We present redshift distortion measurements of the Sloan Digital Sky Survey II Luminous Red Galaxy sample. We find that when combining the normalized quadrupole Q with the projected correlation function $w_p(r_p)$ along with cluster counts (Rapetti et al. 2010), results are consistent with General Relativity. The advantage of combining Q and w_p is the addition of the bias information, when using the Halo Occupation Distribution framework.

We also present improvements to the standard technique of measuring Hubble expansion rates H(z) and angular diameter distances $D_A(z)$ when using the baryonic acoustic feature as a standard ruler. We introduce clustering wedges as an alternative basis to the multipole expansion and show that it yields similar constraints. This alternative basis serves as a useful technique to test for systematics, and ultimately improve measurements of the cosmic acceleration.

402.04 – **Measuring Dark Energy With The Wigglez Survey**

Chris Blake[1], WiggleZ Dark Energy Survey

[1]*Swinburne University of Technology, Australia.*

10:30 AM - 10:40 AM

We present new measurements of the cosmic expansion history and growth history over the last 7 billion years, using data from the WiggleZ Dark Energy Survey of 200,000 galaxy redshifts. We have used baryon acoustic oscillations (BAOs) in the galaxy distribution as a standard ruler to measure the distance-redshift relation up to z=0.73, and present a BAO "Hubble diagram" which provides a powerful cross-check of the use of Type Ia supernovae as standard candles. We additionally use redshift-space distortions in the galaxy clustering pattern to determine the cosmic growth rate with 10% accuracy in redshift bins up to z=0.9. We show that a cosmological constant model of dark energy is able to simultaneously fit both the expansion and growth data. Finally, we measure Alcock-Paczynski distortions in the clustering pattern to reconstruct the expansion history in a non-parametric manner, demonstrating the reality of accelerating

cosmic expansion.

402.05 – **Dark Energy, Expansion History And Non-Gaussianity From The Topology Of The Large-Scale Structure Of The Universe**

Graziano Rossi[1], C. Park[1]

[1]*Korea Institute for Advanced Study (KIAS), Korea, Republic of.*
10:40 AM - 10:50 AM

Constraining different cosmological models and the dark energy equation of state (DE EoS) is usually achieved by analyzing the primordial fluctuations through the power spectrum or the correlation function, or by studying the expansion of the Universe measured with standard candles, rulers (i.e. Baryon Acoustic Oscillations), or populations; the comoving-distance/redshift relation is then used to reconstruct the global expansion history.

As a new alternative method, we propose to adopt the one-dimensional large-scale topology as a cosmic standard ruler, based on the fact that the pattern of the galaxy distribution should be maintained in the course of time on large scales.

In particular, by considering pencil beam surveys and by examining the scale-dependence of the level crossing statistics in different redshift intervals, it is possible to reconstruct the expansion history of the Universe and thus to measure the cosmological parameters governing its expansion. The main parameters and the DE EoS can be estimated by requiring that the rate of level crossings in the radial distribution is constant in time across different redshift intervals, through an iterative minimization procedure. The scale dependence of the one-dimensional level crossings, being an intrinsic topological quantity, is a robust standard ruler, resistant against non-linear gravitational evolution, galaxy biasing, and redshift-space distortions. The technique introduced here is particularly relevant for current and next generation redshift surveys such as BOSS, Wiggle-Z and HETDEX, and will also be used to study primordial non-Gaussianity - in synergy with the Cosmic Microwave Background analysis.

402.06 – **Constraints On The Primordial Non-gaussianity From The Topology Of Large-scale Structure**

Changbom Park[1]

[1]*Korea Institute for Advanced Study, Korea, Republic of.*
10:50 AM - 11:00 AM

We analyze the large-scale distribution of the luminous red galaxies (LRGs) in the final Sloan Digital Sky Survey (SDSS) Catalog to measure the genus topology. The amplitude of the observed genus in the SDSS region reaches 296 with uncertainty of 3.5%. The shape of the genus curve agrees very well with the prediction of perturbation theory and with the mean topology of mock SDSS surveys of LRGs. We used a new large cosmological N-body simulation, Horizon Run 3, that evolved 7210^3 particles in 10815 Mpc/h size box to make 81 mock SDSS LRG surveys along the past light cone surface and to estimate the uncertainties in the measured genus. We constrain the primordial non-Gaussianity parameter f_{NL} from the observed genus curves.

402.07 – **ORIGAMI: Delineating Halos using Phase-Space Folds**

Bridget Falck[1]

[1]*Johns Hopkins University.*
11:00 AM - 11:10 AM

We discuss the ORIGAMI halo-finding algorithm which identifies halo particles as those that have undergone shell crossing, providing a dynamical definition of halo boundaries that is independent of density. ORIGAMI identifies halo particles by tagging them according to whether they have crossed paths with their initial neighbors along 3 orthogonal axes. Additionally, particles that have crossed paths along 2, 1, or 0 axes roughly correspond to filaments, walls, and voids respectively. We compare this method to a standard Friends of Friends halo-finding algorithm and find that ORIGAMI halos are somewhat larger, more diffuse, and less spherical, though the global properties of ORIGAMI halos are in good agreement with other modern halo-finding algorithms.

402.08 – **Lyman Alpha Tomography**

Eric J. Gawiser[1], G. Kanarek[2], R. Ciardullo[3], C. Gronwall[3], MUSYC Collaboration

[1]*Rutgers University,* [2]*Columbia University,* [3]*Penn State University.*
11:10 AM - 11:20 AM

Narrow-band filters are often used to find emission-line galaxies at predetermined redshifts. When applied to high-redshift Lyman Alpha Emitting galaxies, typical surveys include galaxies over a redshift range of delta_z~0.1. Here we show that narrow-band filters with overlapping bandpasses can be used to pinpoint the redshifts of emission-line galaxies to much higher precision, by performing "tomography" that uses the ratio of fluxes between the two filters to identify where in their combined bandpass the emission line is falling. We report an empirical test of this technique, using deep NB4990 and NB5015 Angstrom MUSYC images of the Extended Chandra Deep Field-South obtained at the CTIO 4m telescope (Gawiser et al. 2006, Ciardullo et al. 2011.) While formally a type of photometric redshift, Lyman Alpha Tomography allows the redshifts of these galaxies to be determined to $\mathrm{delta}_z/(1+z)$~0.002, which is the same precision achievable with low-resolution (R~100) spectrographs for these dim, single-emission-line galaxies. Determining the redshifts reveals emission-line luminosities and, when combined with broadband imaging, equivalent widths (EW). Hence this technique enables large galaxy redshift surveys that simultaneously reveal emission-line galaxy luminosity functions and EW distributions without the need to perform resource-intensive spectroscopy. We discuss how the technique can be employed on next generation wide-field imagers, including DECam, Hyper Suprime Cam, and ODI.

This material is based upon work supported by the National Science Foundation under Grant Nos. 0807570, 0807885, 1055919, and by DOE grants DE-GF02-08ER41560 and DE-FG02-08ER41561.

402.09 – **A Numerical Action Method-Based Interpretation of the Dynamical State of the M81 Group**

Bradley Jacobs[1], R. B. Tully[1], E. J. Shaya[2], L. Rizzi[3]

[1]*Univ. Of Hawaii,* [2]*Univ. Of Maryland,* [3]*W. M. Keck Observatory.*
11:20 AM - 11:30 AM

The Numerical Action Method (NAM) is a fully non-linear technique that can be used to analyze galaxy dynamics. We apply NAM to a catalog that includes a complete volume-limited sample of ~150 galaxies within 4.5 Mpc. Each of these nearby galaxies' distances have been measured in a consistent manner by applying the Tip of the Red Giant Method to observations from the Hubble Space Telescope. The combination of distance information and location on the sky with the assumption that galaxies' peculiar motions go to zero at early times set the boundary conditions for minimizing the action of each galaxy. The results from NAM yield complete phase-space information for each galaxy through time. These solutions are not unique, but are assessed based on the degree that they match with each galaxy's measured peculiar radial velocity. This agreement depends on the mass of the galaxies, and thus NAM provides constraints on the galaxies' total dynamical masses. We present a reconstruction of the orbits and estimates of the masses of the galaxies of the M81 group. This work is supported through HST program: SNAP-12546.

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403 – AGN, QSO, Blazars VII

Oral Session – Room 17A – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

403.01 – **LoCuSS: A Dynamical Analysis Of X-ray AGN In Massive Clusters**

Christopher Haines[1], M. J. Pereira[1], E. Egami[1], G. P. Smith[2]

[1]*Steward Observatory,* [2]*University of Birmingham, United Kingdom.*
10:00 AM - 10:10 AM

We present an analysis of the distribution of 48 X-ray AGN in 26 massive clusters at $0.15<z<0.30$ from the LoCuSS survey, combining Chandra imaging with highly-complete spectroscopy of ~10,000 cluster members. We show that X-ray AGN are located preferentially along the caustics of the stacked cluster caustic diagram (velocity offset versus cluster-centric radius). They also completely avoid the region with lowest cluster-centric radii and relative velocities that is dominated by the virialized population accreted earliest into the clusters. Their absolute velocity offsets from the mean cluster redshift are systematically higher than the remainder of the cluster population at the 4.6-sigma level. The mid-infrared bright X-ray AGN also have higher velocity offsets with respect to their IR-dim counterparts.

We show that the X-ray AGN found in massive clusters are an infalling population yet to encounter the dense ICM, and whose nuclear activity is very effectively shut down upon accretion into the cluster. These results are consistent with the view that for galaxy to host an X-ray AGN they should be the central galaxy within their dark matter halo, and have a ready supply of cold gas.

403.02 – **New Constraints on the Broad Line Region**

David Floyd[1], A. J. Ruff[2], R. L. Webster[2]

[1]*Monash University, Australia,* [2]*University of Melbourne, Australia.*
10:10 AM - 10:20 AM

We highlight recent advances in Gravitational Microlensing and Photoionization modelling that are beginning to resolve the structure and physics of the central engine in quasars. While quasar accretion disks and broad line regions will remain well beyond the resolution limits of our telescopes for the foreseeable future, microlensing provides us with effective resolutions ~micro-arcseconds, sufficient to study their structure. New photoionization modelling that fully accounts for the structure of the hydrogen atom allows individual quasar spectra to place strong constraints on the physical conditions in their broad line regions. I present application of these methods to IRTF, Gemini and VLT spectra.

403.03 – **Time Variable Broad Line Emission in NGC 4203: Evidence for Stellar Contrails**

Nicholas A. Devereux[1]

[1]*Embry-Riddle Aeronautical Univ..*
10:20 AM - 10:30 AM

Dual epoch spectroscopy of the lenticular galaxy, NGC 4203, obtained with the Hubble Space Telescope has revealed that the double-peaked component of the broad Hα emission line is time variable, increasing by a factor of 2.2 in brightness between 1999 and 2010. Modeling the gas distribution responsible for the double-peaked profiles indicates that a ring is a more appropriate description than a disk and most likely represents the contrail of a red supergiant star that is being tidally disrupted at a distance of ~1500 AU from the central black hole. There is also a bright core of broad Hα line emission that is not time variable and identified with a large scale inflow from an outer radius ~ 1 pc. If the gas number density is $\geq 10^6$ cm^{-3}, as suggested by the absence of similarly broad [O I] and [O III] emission lines, then the steady state inflow rate is ~ 2×10^{-2} $M_\odot$/yr which exceeds the inflow requirement to explain the X-ray luminosity in terms of radiatively inefficient accretion by a factor of ~ 6. The central AGN is unable to sustain ionization of the broad line region, the discrepancy is particularly acute in 2010 when the broad Hα emission line is dominated by the contrail of the in-falling supergiant star. However, ram pressure shock ionization produced by the interaction of the in-falling supergiant with the ambient interstellar medium may help alleviate the ionizing deficit by generating a mechanical source of ionization supplementing the photoionization provided by the AGN.

Support for Program number HST AR-11752.01-A 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.

403.04 – **The Herschel View Of The Palomar-Green Qso: Measuring The Ism Content Of A Large Volume Limited Sample Of Nearby Quasars**

Andreea Petric[1], L. Ho[2], N. Scoville[1], N. Flagey[1]

[1]*Caltech,* [2]*Carnegie.*
10:30 AM - 10:40 AM

Central Black holes (BHs) with are an integral component of massive galaxies and they play critical role in the life cycle of galaxies - the feedback associated with their high luminosities and strong winds/jets can both energize and remove the galactic ISM; they thus dramatically affect the subsequent galactic evolution (see review in Ho 2004). Here we present PACS and SPIRE data of a complete volume limited of 87 PG QSOs at z < 0.5. We combine these data with SPITZER 3.5 to 24 microns data to determine the amount of cold ISM responsible for providing the fuel for both accretion onto the BH and star-formation. We compare the masses and temperatures of the dust with the size of the BH as well as host properties.

403.05 – **Observing the Fast Growth of Black Holes at z~4.8**

Benny Trakhtenbrot[1], H. Netzer[1], P. Lira[2], O. Shemmer[3]

[1]*Tel-Aviv University, Israel,* [2]*Universidad de Chile, Chile,* [3]*University of North Texas.*
10:40 AM - 10:50 AM

I will present our team's efforts to measure black hole masses and accretion rates in several high-redshift samples of AGNs, based on extensive NIR spectroscopic campaigns. I will particularly focus on a large sample of z~4.8 AGNs, which were observed in a combined VLT-Gemini campaign. This sample probes the most massive BHs at this epoch, but shows lower masses and higher accretion rates than those of z~2-3.5 sources. When combining these samples together, a clear evolutionary sequence is evident: the z~4.8 BHs grow through Eddington-limited accretion from a broad range of seed masses; their subsequent growth, at duty cycles of ~10-20%, forms the most massive BHs observed at z~2.

403.06 – **STARE: Testing Black Hole Mass Measurements in Active Galaxies**

Misty C. Bentz[1], STARE Collaboration

[1]*Georgia State University.*
10:50 AM - 11:00 AM

Black hole masses are fundamental measurements that inform our knowledge of the formation and evolution of galaxies throughout cosmic time. The technique of reverberation mapping uses the time variability of active galactic nuclei (AGNs) to directly measure the masses of supermassive black holes in galaxy nuclei. The Southern Telescope AGN Reverberation Experiment (STARE) collaboration was founded to carry out spectroscopic monitoring of AGNs with the SMARTS 1.5m telescope at CTIO and photometric monitoring through a worldwide network of telescopes. The first STARE campaign is monitoring four AGNs from August through November 2011, and another campaign is planned for spring 2012. The monitoring datasets we are acquiring will allow us to track the continuum fluctuations and the detailed response of the broad emission lines, enabling us to directly test the consistency of black hole mass measurements derived from complementary techniques and to probe the detailed geometry and kinematics of the photoionized gas on scales ~0.01 pc from each central black hole. I will discuss initial results from the 2011 STARE campaign.

403.07 – **Are LINERs AGN?**

Renbin Yan[1], M. R. Blanton[1]

[1]*New York University.*
11:00 AM - 11:10 AM

Ever since their discovery, the nature of low ionization nuclear emission-line regions (LINERs) has been hotly debated. Some authors treat them as AGNs, others argue they are not AGNs but powered by shocks or hot old stars. No universal agreement has been reached. On the other hand, early-type galaxies frequently contain spatially extended warm ionized gas and have spectra similar to LINERs. How is this large-scale emission related to the nuclear LINERs? Because LINER-like spectrum is the most common spectral type found in early-type galaxies in both nuclear and integrated spectra, understanding its nature is important to numerous topics in astrophysics.

By comparing nuclear aperture spectroscopy from the Palomar survey with larger scale data from the Sloan Digital Sky Survey, we find the line emission in the majority of passive red galaxies is spatially extended. We detect strong line ratio gradients with radius in [NII]/Halpha, [SII]/Halpha, and [OIII]/[SII], requiring the ionization parameter to increase outwards. Combined with a realistic gas density profile, this outward increasing ionization parameter convincingly rules out AGN as the dominant ionizing source, and strongly favors distributed ionizing sources. Sources that follow the stellar density profile can additionally reproduce the observed luminosity-dependence of the line ratio gradient. Post-AGB stars provide a natural ionization source candidate, though they have an ionization parameter deficit. Velocity width differences among different emission lines disfavor shocks as the dominant ionization mechanism, and suggest that the interstellar medium in these galaxies contains multiple components. We conclude that the line emission in most LINER-like galaxies found in large aperture (>100pc) spectroscopy is not primarily powered by AGN activity and thus does not trace the AGN bolometric luminosity. However, they can be used to trace warm gas in these early-type galaxies.

403.08 – **Fresh Activity in Old Systems: Radio AGN in Fossil Groups of Galaxies**

Kelley M. Hess[1], E. M. Wilcots[2], V. L. Hartwick[2]

[1]*Univ. Of Cape Town, South Africa,* [2]*Univ. Of Wisconsin-Madison.*
11:10 AM - 11:20 AM

We present the first systematic VLA 1.4 GHz radio survey of candidate fossil galaxy groups: systems believed to have formed over a gigayear in the past through the merger of group members into a single, massive elliptical galaxy. We find that 3 of the candidates are clearly not fossil groups based on new photometry from SDSS DR7. Of the remaining 30 fossil groups, we find that 67% contain a radio-loud ($L_{1.4GHz} > 10^{23}$ W Hz^{-1}) active galactic nucleus (AGN) at the center of the dominant elliptical galaxy. We compare the radio observations with optical photometry and X-ray luminosities in order to connect the properties of the AGN with the properties of the group environment, or the properties of the remnant elliptical galaxy. The radio luminosity may be weakly correlated to the X-ray luminosity of the halo, however there is no correlation between the radio and optical luminosities of the central galaxy. This suggests that the AGN frequency in fossil groups is independent of their formation history. We compare the AGN frequency with that of other galaxy populations. Finally, we discuss the possibilities for fueling an AGN in the present day, long after the fossil group has undergone its last major merger.

403.09 – **HST WFC3/IR Grism: Discovery of Three Accreting Black Holes in a Galaxy at z~1.35**

Kevin Schawinski[1], M. Urry[1], E. Treister[2], B. Simmons[1], P. Natarajan[1], E. Glikman[1]

[1]*Yale University,* [2]*Universidad de Concepcion, Chile.*

11:20 AM - 11:30 AM

We present Hubble Space Telescope WFC3/IR grism observations of a clumpy star-forming galaxy at z = 1.35 with 1E6 − 1E7 Msun rapidly growing black holes in three separate sub-components of the host galaxy. We discuss the properties of this Triple AGN system and its implications for black hole growth and black hole seed formation at late times.

404 – Circumstellar Disks

Oral Session – Room 12A – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

404.01 – **Keck AO Observations of the Protostellar Disk around Radio Source I in the Orion Kleinmann-Low Nebula**

Breann Sitarski[1], M. R. Morris[1], E. E. Becklin[1], A. M. Ghez[1], J. R. Lu[2], A. Stolte[3], H. Zinnecker[4]

[1]*UCLA,* [2]*University of Hawaii,* [3]*Universität Bonn, Germany,* [4]*Astrophysikalisches Institut Potsdam, Germany/SOFIA Science Center.*

10:00 AM - 10:10 AM

Radio Source I in the Kleinmann-Low Nebula in Orion has recently been subject to intense scrutiny as the likely source of much of the luminosity and kinetic outflow energy in this massive-star-forming region. Two groups (Goddi et al. 2011 and Reid et al. 2007) have produced 7-mm radio continuum evidence for a disk. Furthermore, the inferred disk is perpendicular to an outflow seen most clearly in both maser and non-maser emission from the SiO molecule (e.g. Plambeck et al. 2009; Matthews et al. 2010). Using imaging with laser guide star adaptive optics on the Keck II Telescope, we have made the first detection of a infrared counterpart to the disk surrounding Source I, which is most prominently seen in a color image made with L' and Ms filters and is not present at K'. We interpret our data as the illuminated surface of a nearly edge-on disk of which only the northern surface is visible; the opposite, more distant surface lies behind the opaque disk. The collimated outflow oriented perpendicular to the disk may also be present in our L'/Ms color image. The infrared counterpart to Source I overlaps the nearby infrared feature IRc 2A, which we resolve into two peaks. This suggests that the distribution of interstellar gas surrounding the Source I disk is inhomogeneous; IRc 2A may consist of fortuitously placed cloud clumps that are illuminated and heated by Source I. We further present our preliminary analysis of the proper motions of sources I, n, IRc 2A, and IRc 2C, in which we explore whether IRc 2A and Source I share a common motion.

404.02D – **Circumstellar Disks Around Rapidly Rotating Be-type Stars**

Yamina Touhami[1]

[1]*Georgia State University.*

10:10 AM - 10:30 AM

Be stars are rapidly rotating B-type stars that eject large amounts of gaseous material into a circumstellar equatorial disk. The existence of this disk has been confirmed through the presence of

several observational signatures such as the strong hydrogen emission lines, the IR flux excess, and the linear polarization detected from these systems. Here we report simultaneous near-IR interferometric and spectroscopic observations of circumstellar disks around Be stars obtained with the CHARA Array long baseline interferometer and the Mimir spectrograph at Lowell observatory. The goal of this project was to measure precise angular sizes and to characterize the fundamental geometrical and physical properties of the circumstellar disks. We were able to determine spatial extensions, inclinations, and position angles, as well as the gas density profile of the circumstellar disks using an elliptical Gaussian model and a physical thick disk model, and we show that the K-band interferometric angular sizes of the circumstellar disks are correlated with the H-alpha angular sizes. By combining the projected rotational velocity of the Be star with the disk inclination derived from interferometry, we provide estimates of the equatorial rotational velocities of these rapidly rotating Be stars.

404.03 – **A Disappearing Dusty Debris Disk**

Carl Melis[1], B. Zuckerman[2], I. Song[3], J. H. Rhee[4], M. S. Bessell[5], S. J. Murphy[5]

[1]*UC San Diego,* [2]*UC Los Angeles,* [3]*University of Georgia,* [4]*Eureka Scientific,* [5]*Australian National University.*

10:30 AM - 10:40 AM

We have identified a nearby young star that went from hosting a densely populated dust disk in its terrestrial planet zone to hosting a meager warm dust disk in the period of only one to two years. We will discuss observations of this system that led to this remarkable finding and will suggest mechanisms that could act to rapidly deplete a dusty disk.

Funding for this research came from NASA grants to UCLA and University of Georgia, an LLNL-Minigrant to UCLA, from the Spitzer Visiting Graduate Student Program, and from the NSF through award No. AST-1003318.

404.04 – **Planetary Construction Zones in Occultation: Eclipses by Circumsecondary and Circumplanetary Disks and a Candidate Eclipse of a Pre-Main Sequence Star in Sco-Cen**

Eric E. Mamajek[1], A. C. Quillen[2], M. Pecaut[2], F. Moolekamp[2], E. L. Scott[2], M. A. Kenworthy[3], A. Collier Cameron[4], N. Parley[4]

[1]*CTIO, University of Rochester,* [2]*University of Rochester,* [3]*Leiden University, Netherlands,* [4]*University of St. Andrews, United Kingdom.*

10:40 AM - 10:50 AM

The large relative sizes of circumplanetary and circumstellar disks imply that they might be seen in eclipse in stellar light curves. We present photometric and spectroscopic data for a complex disk eclipse of a post-accretion, solar-mass pre-main sequence star. The star 1SWASP J140747.93-394542.6 is a ~16 Myr-old member of the Upper Centaurus-Lupus subgroup of Sco-Cen at 130 pc, and was discovered in a spectroscopic survey for new low-mass Sco-Cen members by Pecaut & Mamajek. SuperWASP and ASAS V-band time series photometry reveal that this star exhibited a remarkably long, deep, and complex eclipse event in April 2007. At least 5 multi-day dimming events of >0.5 mag are identified, with an asymmetric >3.3 mag deep eclipse bracketed by two pairs of ~1 mag eclipses symmetrically occurring +-12 days and +-26 days before and after. We place a firm lower limit on the period of the eclipser of 850 days. We hypothesize that this star is being eclipsed by a low-mass object with an orbiting dust disk with significant radial substructure ("rings" and gaps) and mass on the order of lunar masses. Combining theoretical predictions of the sizes and masses of circumplanetary disks around young gas giants with observational constraints on the incidence of such planets, shows that their eclipses should be of sufficient optical depth and duration to be plausibly detectable, albeit extraordinarily rarely. LSST surveys of post-accretion stars (~10 Myr) should yield disk eclipses around at least ~10^{-4} of the stars. Eclipses by circumplanetary and circumsecondary disks will provide us fine-scale observational constraints on the physical and chemical conditions of the dust and gas which spawn satellite systems around gas giant planets and planetary systems around stars. This research was supported by NSF grant AST-1008908 and funds from the School of Arts and Sciences at the University of Rochester.

404.05 – **Studying the Gas in Circumstellar Disks with Dust Gaps and Holes**

Catherine Espaillat[1]

[1]*Harvard-Smithsonian Center for Astrophysics.*

10:50 AM - 11:00 AM

Forming planets should interact with the surrounding accretion disk, clearing the material around themselves and leaving behind gaps in the disk. Stars with inner holes in their disks have been detected and are labeled as transitional objects. A few years ago, Spitzer identified a new class of "pre-transitional disks" which have gaps rather than holes - they have an inner disk, a gap, and an outer disk. In order to explore the relationship between the dust and gas in the inner regions of these objects, we obtained high-resolution Spitzer IRS spectra for a number of transitional and pre-transitional objects. We will present detections of 12.81 micron Neon fine structure emission from our sample. In addition, we will discuss the mass accretion rates of (pre-)transitional disks relative to "full" disks with no gaps or holes.

404.06 – **Modeling Accretion Disk Formation In Binary Systems**

Martin Huarte Espinosa[1], A. Frank[1], E. G. Blackman[1], J. J. Carroll-Nellenback[1], J. Nordhaus[1]

[1]*University of Rochester.*

11:00 AM - 11:10 AM

We present new results of 3-D Adaptive Mesh Refinement (AMR) simulations exploring the evolution of accretion disks formed via wind capture in binary systems. Accretion onto a secondary star is one paradigm to explain a sub-class of jets in Planetary Nebulae and X-ray binaries. We consider an AGB primary and a main sequence secondary star with separations of order 20AU. As the stars orbit, the primary ejects a dense spherical wind and some of this material is captured by the secondary forming an accretion disk. The AMR allows us to follow the disk flow down to scales of order 0.2 AU. We investigate the distribution of the disks' density and velocity fields, as well as their accretion rates and angular momenta as a function of orbital period. Our calculations seem to suggest that the disk's total angular momentum vector tilts as the simulations evolve.

405 – Extrasolar Planets II

Oral Session – Ballroom F – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

405.01 – **The California-Kepler Survey: Precise Planet Radii and Metallicities**

Andrew Howard[1], G. W. Marcy[1], J. A. Johnson[2], T. D. Morton[2], H. Isaacson[1]

[1]*UC Berkeley,* [2]*Caltech.*

10:00 AM - 10:10 AM

For the small subset of sub-Neptune-size planets with well-measured masses and radii, bulk density varies by an order of magnitude, owing to great diversity in composition and atmospheric content. The ensemble of small planets discovered by Kepler have a radius distribution that rises steeply with decreasing size, with close-in sub-Neptune-size planets being an order of magnitude more common than hot Jupiters. However, the detailed structure of the planet radius distribution remains partially veiled by poorly known stellar properties from the Kepler Input Catalog (KIC). Correlations of planet properties with stellar properties are similarly out of focus or unknown. To measure these crucial properties, our team is compiling a new catalog of stellar parameters for the Kepler planet hosts based on LTE modeling of high-resolution Keck-HIRES spectra. I will present initial results from this catalog. We expect detailed structure of the planet radius distribution to emerge, including deviations from a power-law model that suggest common planet sizes and preferred formation scenarios. It will also shed light on the variations of planet occurrence with orbital distance and stellar mass/metallicity, offering important clues for the formation of small worlds.

405.02D – **Retrieval of Atmosphere Structure and Composition of Exoplanets from Transit Spectroscopy**

Jae-Min Lee[1], L. N. Fletcher[1], P. G. J. Irwin[1]

[1]*Atmospheric, Oceanic and Planetary Physics, University of Oxford, United Kingdom.*

10:10 AM - 10:30 AM

Recent spectroscopic observations of transiting exoplanets of HD 189733b, HD 209458b, GJ 436b and GJ 1214b provide the best chance of characterizing the thermal structure and composition of their atmospheres. Here we have applied an optimal estimation retrieval architecture to fit exoplanet spectra to determine the thermal structure and composition by solving the inverse problem. The development of a suite of radiative transfer and retrieval tools for exoplanet atmospheres is explained, building upon a rapid correlated-k approximation and a retrieval algorithm extensively used in our own solar system. With these tools we discuss the best-fitting spectrum to the measurements with the best-estimated solution (i.e. the maximum a posteriori solution) for the vertical temperature structure and molecular abundances. Additionally, the contribution functions and the vertical sensitivity to the molecules are fully utilized to interpret transmission and emission spectra, probing the structure and composition of the atmosphere. Furthermore, the analysis of the cross-correlation functions permits us to quantify the uncertainties in the degeneracy between the retrieved atmospheric properties based on the current quality of the data. This sheds light on the range of diverse interpretations offered by other studies so far. It also allows us to scrutinize further atmospheric features by maximizing the capability of the current retrieval algorithm and to demonstrate the benefit of using as broad a spectral range as possible, with clear implications for the next generation of exoplanetary missions.

405.03D – **The Hypatia Catalog: Chemical Abundances in the Habitable Solar Neighborhood**

Natalie R. Hinkel[1]

[1]*Arizona State University.*

10:30 AM - 10:50 AM

I have compiled spectroscopic abundance determinations for 44 elements across 1224 stars within 160 pc of the Sun from literature sources to produce the Hypatia Catalog. The goal of the Hypatia Catalog is to examine nearby stars and regions in the solar neighborhood for chemical abundance trends, specifically those enhanced with bio-essential elements, namely: C, N, O, Mg, Si, S, and Fe, for additional information in the search for exoplanets. Hypatia is based upon The Catalog of Nearby Habitable Stellar Systems, or stars in the solar neighborhood that could potentially host habitable exoplanets, depending on stellar distances, variability, multiplicity, kinematics, and spectral classification. I find that the element abundance maps of Hypatia stars suggest [1] stars in the solar neighborhood are consistent with solar abundances, [2] the evolutionary history of each element is consistent with mean chemical evolution models, [3] there are no significant statistical correlations in the abundances with respect to position, radial distance, or velocity - suggesting the solar neighborhood is well mixed, [4] possible confirmation of trends known to be found in the abundances of verified exoplanet hosts, and [5] there are ``habitability windows'' located on the sky at (20.6^h, -4.8^o) and (22.6^h, -48.5^o) that exhibit enhanced abundances of bio-essential elements which may be of use in targeted or beamed searches.

405.04 – **C/O Ratios In Exoplanetary Atmospheres - New Results And Major Implications**

Nikku Madhusudhan[1]

[1]*Princeton University.*

10:50 AM - 11:00 AM

Recent observations are allowing unprecedented constraints on the carbon-to-oxygen (C/O) ratios of giant exoplanetary atmospheres. Atmospheric C/O ratios provide important constraints on chemical and dynamical processes in the atmospheres, and on the planetary interior compositions and formation scenarios. In addition, for super-Earths, the potential availability of water and oxygen, and hence the notion of `habitability', is contingent on the C/O ratio assumed. Typically, an oxygen-rich composition, motivated by the solar nebula C/O of 0.5, is assumed in models of exoplanetary formation, interiors, and atmospheres. However, recent observations of exoplanetary atmospheres are suggesting the possibility of C/O ratios of 1.0 or higher, motivating the new class of Carbon-rich Planets (CRPs). In this talk, we will present observational constraints on atmospheric C/O ratios for an ensemble of transiting exoplanets and discuss their implications on the various aspects of exoplanetary characterization described above. Motivated by these results, we propose a two-dimensional classification scheme for irradiated giant exoplanets in which the incident irradiation and the atmospheric C/O ratio are the two dimensions. We demonstrate that some of the extreme anomalies reported in the literature for hot Jupiter atmospheres can be explained based on this 2-D scheme. An overview of new theoretical avenues and observational efforts underway for chemical characterization of extrasolar planets, from hot Jupiters to super-Earths, will be presented.

405.05 – **Infrared Spectroscopy of the Transiting Exoplanets HD189733b and XO-1 Using Hubble WFC3 in Spatial Scan Mode**

Drake Deming[1], A. Wilkins[1], P. McCullough[2], N. Madhusudhan[3], E. Agol[4], A. Burrows[3], D. Charbonneau[5], M. Clampin[6], J. Desert[5], R. Gilliland[2], H. Knutson[7], A. Mandell[6], S. Ranjan[5], S. Seager[8], A. Showman[9]

[1]*Univ. of Maryland,* [2]*STScI,* [3]*Princeton Univ.,* [4]*Univ. of Washington,* [5]*CfA,* [6]*GSFC,* [7]*Caltech,* [8]*MIT,* [9]*Univ. Arizona.*

11:00 AM - 11:10 AM

Infrared transmission spectroscopy of the exoplanets HD189733b and XO-1 has been previously reported by Swain et al. and Tinetti et al. based on observations using the NICMOS instrument on the Hubble Space Telescope. The robustness of those results has been questioned, because derivation of the exoplanetary spectrum required decorrelating strong instrumental systematic effects in the NICMOS data. We here discuss results from HST/WFC3 grism 1.1-1.7 micron spectroscopy of these planets during transit. WFC3 instrumental signatures are smaller in both amplitude and complexity as compared to NICMOS. Moreover, we use a new spatial scan mode to trail the stars perpendicular to the dispersion direction during WFC3 exposures, and this increases the efficiency of the observations and reduces persistence effects in the detector. We derive the 1.4-micron water absorption spectrum of these planets during transit, discuss implications for these exoplanetary atmospheres, and compare our results to the NICMOS spectroscopy.

405.06 – **New Imaging of the beta Pictoris Planet and Debris Disk**

Thayne M. Currie[1], C. Thalmann[2], S. Matsumura[3], N. Madhusudhan[4], A. Burrows[4], M. Kuchner[1]

[1]*NASA-Goddard Space Flight Center,* [2]*University of Amsterdam, Netherlands,* [3]*University of Maryland,* [4]*Princeton University.*

11:10 AM - 11:20 AM

We present new direct imaging results on the planet and debris disk surrounding 12 Myr-old beta Pictoris. Using an updated version of our reduction pipeline, we extract a new detection of beta Pic b from 2008 VLT/NaCo data at a sub-Jupiter projected separation (~4 AU), about 1.5 lambda/D. We also obtain a high signal-to-noise rereduction of L' data taken in 2009 December. Intriguingly, the planet's orbit is aligned with the major axis of the outer disk (Omega ~ 31 deg) but is probably misaligned with the warp/inclined disk at 80 AU, often cited as a signpost for the planet's existence. We also present new images of the beta Pic debris disk and discuss any evidence for a 2nd massive gas giant planet in the system.

405.07 – **First: Florida Ir Silicon Immersion Grating Spectrometer**

Jian Ge[1], B. Zhao[1], J. Wang[1], X. Wan[1], S. Powell[1]

[1]*Univ. of Florida.*

11:20 AM - 11:30 AM

The FIRST silicon immersion grating spectrometer is being developed at UF to search for habitable Earth-like planets around M dwarfs and giant planets around young active stars. This compact cryogenic IR instrument is designed to have a spectral resolution of R=72,000 at 1.4-1.8 μm with a silicon immersion grating and R=60K at 0.8-1.35 μm with an R4 echelle. The goal is to reach a long term Doppler precision of 1-3 m/s for bright M dwarfs. The FIRST silicon immersion grating, with 54.74 degree blaze angle and 16 l/mm groove density, has been fully characterized in the lab. The 50x50 mm square grating entrance pupil is coated with a single layer of anti-reflection coating resulting in a 2.1% measured reflection loss. The grating surface was coated with a gold layer to increase grating surface reflectivity. It has produced R=110,000 diffraction limited spectral resolution at 1.523 micron in a lab test spectrograph with 20 mm pupil diameter. The integrated scattered light is less than 0.2\% and grating has no visible ghosts down

to the measuring instrument noise level. The grating efficiency is 69\% at the peak of the blaze. This silicon immersion grating is ready for scientific observations with FIRST. FIRST is scheduled to be integrated in the lab during the spring of 2012 and see the first light at an astronomical telescope (TBD) the summer of 2012.

406 – Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS) I

Special Session – Ballroom E – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

The Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS)is the largest survey yet conducted with the Hubble Space Telescope.It is designed to document the first third of galactic evolution, fromredshift z ~ 8 to z ~ 1.5. It will image more than 250,000 distantgalaxies using three separate cameras on board HST from the mid-UV tonear-IR, and it will find and measure Type Ia SNe beyond z > 1.5 andtest their accuracy as standard candles for cosmology. Five premiersky regions are selected, all with extensive multi-wavelength imagingand spectroscopy from X-ray to radio.

The heart of CANDELS is the WFC3/IR camera, which opens up extensivehigh-resolution near-IR imaging on Hubble for the first time.WFC3/IR's longer wavelengths reveal the true structure of z ~ 2galaxies as outlined by older stars and can find and measure distantType Ia SNe to higher redshifts than previously possible. WFC3/IRreturns superbly accurate YJH photometry that goes 10 times fainterthan ground data, permitting the first complete census of galaxies inthe distant Universe down to a few billion solar masses out to z ~ 8.

The CANDELS special sessions will give an overview of CANDELS andpresent early science results from the first year of data. CANDELS Iwill concentrate on the structure and morphologies of z ~ 2 galaxiesand their relation to stellar mass and star-formation activity. Thenew CANDELS morphological classification scheme will be described, andmorphologies for z ~ 2 X-ray AGN summarized. WFC3 grism observationsin CANDELS fields will be described.

406.01 – **Introduction to the CANDELS Survey**

S. M. Faber[1], H. C. Ferguson[2], CANDELS Team

[1]*UC, Santa Cruz,* [2]*STScI.*

10:00 AM - 10:13 AM

The Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS) is designed to document the first third of galactic evolution, from $z \sim 8$ to $z \sim 1.5$. It will image >250,000 distant galaxies using three separate cameras on the Hubble Space Telescope from the mid-UV to near-IR and will find and measure Type Ia supernovae beyond $z > 1.5$ to test their accuracy as standard candles for cosmology. Five premier sky regions are selected, each with extensive multi-wavelength data. The use of five widely separated fields mitigates cosmic variance and yields statistically robust and complete samples of galaxies down to a stellar mass of 10^9 solar masses at $z \sim 2$ and to the knee of the UV luminosity function at $z \sim 8$. The survey covers approximately 800 arcmin^2 and is divided into two parts. The CANDELS/Deep survey (5-sigma point-source limit $H_{AB} = 27.7$ mag) covers ~125 arcmin^2 within GOODS-N and GOODS-S on ten separate visits. The CANDELS/Wide survey (5-sigma point-source limit $H_{AB} \sim 27.0$ mag) images all of GOODS and three additional fields (EGS, COSMOS, and UDS) and covers the full area on two visits. Together with the Hubble Ultradeep Fields, this strategy replicates the “wedding cake” approach that has proven effective for extragalactic surveys. Extensive parallel imaging with the Advanced Camera for Surveys creates a new ACS mosaic in UDS, deepens four existing ones, and provides high-resolution Hubble panchromatic imaging from 0.40 m to 1.6 m. Multiple visits to all fields permit variability studies and supernovae searches, and special deep UV observations cover half of GOODS-N. Data from the survey are non-proprietary and are useful for a wide variety of science investigations. In this talk, we review the scientific goals; observational requirements; field selection, geometry, and observing design; schedule; and the public data products.

406.02 – **The CANDELS Morphological Classification System for z ~ 2 Galaxies**

Jeyhan S. Kartaltepe[1], CANDELS Team

[1]*National Optical Astronomy Observatory.*

10:15 AM - 10:28 AM

We present the initial results of an ambitious program to visually classify galaxies in all of the CANDELS fields down to a magnitude limit of H<24.5. Using a detailed visual classification scheme and many volunteer classifiers, we have classified galaxies at two different depths in the GOODS-S field. Using this unique data set, we compare the results among the different classifiers in order to quantify how reliably galaxies can be classified as a function of magnitude and redshift. We study the classifier to classifier variation as well as the differences between two different depths (2 and 4-orbit HST depths). Additionally, we compare these classifications to several automated classification techniques to quantify how well they work as a function of redshift and study the affects of morphological K-corrections.

406.03 – **Quenching and Galactic Structure: Why Did SFR Shut Down in Massive Galaxies?**

Eric F. Bell[1], CANDELS team

[1]*University of Michigan.*

10:30 AM - 10:43 AM

We use HST/WFC3 imaging from the CANDELS multicycle treasury survey, in conjunction with the Sloan Digital Sky Survey, to explore the evolution of galactic structure for galaxies with stellar masses in excess of 3x10^10 solar masses from z=2.2 to z=0, a time span of 10Gyr. We explore the relationship between stellar mass, star formation activity and the structural parameters of galaxies as determined from parametric fits to the surface brightness profiles of galaxies. We confirm the dramatic evolution from z=2.2 to the present day in the number of non star-forming galaxies above 3x10^10 solar masses reported by other authors --- we find that the vast majority of these quiescent systems have concentrated light profiles, as parametrized in this work using galaxy Sersic index, and the population of concentrated galaxies grows similarly rapidly. We examine the joint distribution of star formation activity, Sersic index, stellar mass, M/R (a proxy for velocity dispersion) and stellar surface density. Quiescence correlates poorly with stellar mass at all z<2.2; given the <0.2 dex scatter between halo mass and stellar mass at z~0 inferred by More et al. 2011; MNRAS,410,210, this argues against halo mass being the only factor determining quiescence). Quiescence correlates most tightly with Sersic index, and correlates well with 'velocity dispersion' and stellar surface density. Yet, there is significant scatter in any of these correlations: a fraction of systems with high Sersic index form stars, and some quiescent galaxies have significant disks. Noting the rarity of quiescent galaxies without prominent bulges, we suggest that a prominent bulge (and, perhaps by association, a supermassive black hole) is a necessary but not sufficient condition for quenching star formation over the last 10Gyr; such a result is qualitatively consistent with the expectations of the AGN feedback paradigm. This work is supported by HST grant GO-12060.

406.04 – **Clumps in Star-forming Galaxies at High Redshifts and Their Evolution**

Swara Ravindranath[1]

[1]*IUCAA, India.*

10:45 AM - 10:58 AM

Most of the star-forming galaxies at high redshifts, when observed at restframe UV wavelengths are found to contain kiloparsec-sized clumps, with stellar masses ~ 10^9 $M_\odot$ on average. These star-forming clumps having masses and sizes that are orders of magnitude larger than the starbursts observed at low redshifts, are a unique feature at z>1. In hydrodynamical simulations, the "clump phase" is a natural consequence of rapid gas accretion, large gas fraction, and large turbulence in the disk galaxies at early cosmic epochs. The near-infrared images from GOODS-ERS, HUDF, and CANDELS allows to examine the restframe optical properties of the clumps in unprecedented detail, and to obtain important constraints on their masses, star formation rates, color, M/L, and stellar ages. In this talk, I will present the recent results based on the observed restframe UV-optical properties of clumps, and discuss their implications in the context of current theories on clump formation and evolution.

406.05 – **Morphology and Structure of AGN Host Galaxies at z ~ 2**

Dale Kocevski[1], S. Faber[1], K. Nandra[2], J. Trump[1], D. Koo[1], A. Koekemoer[3]

[1]*University of California, Santa Cruz,* [2]*Max Planck Institute for Extraterrestrial Physics,* [3]*STScI.*

11:00 AM - 11:10 AM

Using HST/WFC3 imaging taken as part of the CANDELS survey, we have examined the rest-frame optical morphologies of AGN host galaxies at z~2 to determine the role that major galaxy mergers play in triggering AGN activity at this redshift. Our sample consists of 72 moderate-luminosity (Lx~10^42-44 erg/s) AGN at 1.5<z<2.5 selected using the 4 Msec Chandra observations in the Chandra Deep Field South. Employing visual classifications, we have determined that AGN hosts do not exhibit merger or interaction signatures more often than non-active galaxies of similar mass at this redshift. Furthermore, although the AGN appear to favor bulge-dominated and

spheroidal hosts compared to our control sample, a majority of the AGN are hosted by disk-like galaxies. Our results suggest that the bulk of the X-ray luminous AGN population at z~2 could not have been triggered by a major merger event in the recent past. Instead it appears that secular processes or possibly cold-flow accretion plays a greater role in triggering AGN activity at z~2 than previously thought.

406.06 – **Infrared Spectroscopy with HST: Grism Results in the CANDELS Fields**

Benjamin J. Weiner[1]

[1]*University of Arizona.*

11:12 AM - 11:25 AM

The CANDELS survey takes slitless grism spectroscopy with HST's WFC3-IR to follow up high-redshift supernovae discovered in CANDELS photometry. These deep grism exposures yield spectra for many galaxies in each pointing, in addition to the SN and its host. They complement shallower IR grism surveys by independent programs that cover most of the CANDELS area. HST IR grism data yields low-resolution spectra at 1-1.6 microns for most galaxies in the field of view. The low background and multiplex advantage make it an extremely powerful probe of galaxies at z=1-3. We present several science programs by CANDELS members with infrared grism spectra, including: the properties of extreme high-EW emission-line galaxies at z=1.8; low-metallicity galaxies and low-luminosity AGN at z=2; extinction and star formation rate measurements from IR detections of H-alpha at z~1; the spatial distribution of star formation in galaxies, measured at HST's high spatial resolution; and restframe optical continuum spectroscopy at z~2.

407 – Science Highlights from NASA's Astrophysics Data Analysis Program I

Special Session – Room 16B – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

Over the years, NASA has invested heavily in the development and execution of an extensive array of space astrophysics missions. 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 from investigators supported under the ADAP Program.

407.01 – **Survey of Infrared Variability of Young Stellar Objects in Nearby Molecular Clouds**

Tracy L. Huard[1], S. Storm[1], L. G. Mundy[1]

[1]*Univ. of Maryland.*

10:00 AM - 10:20 AM

The Spitzer Space Telescope archive provides a means for studying mid-infrared variability in large numbers of young stellar objects (YSOs) in different star-forming regions. We are conducting such a study, as part of NASA's Astrophysics Data Analysis Program (ADAP), to identify those YSOs exhibiting variability and to characterize the frequency, magnitude, and color of this variability. Our results for isolated core regions, for example, demonstrate that (70 +/- 20)% of Class I and Flat-spectrum YSOs exhibit variability over timescales of 1-2 years, while only (24 +/- 8)% of Class II and III YSOs appear to be variable over these times, suggestive of a dependence on evolutionary class. In contrast, we find no such dependence in the IC 5146 cluster forming region or the Perseus or Serpens regions, where ~35-45% of the YSOs exhibit variability. In general, the variable YSOs brighten or dim consistently across the IRAC 3.6-8.0 micron bands; the mid-infrared color changes are typically inconsistent with variable line-of-sight extinction. The magnitude of maximum IRAC variability for many YSOs is inconsistent with starspots as the dominant cause. Instead, intermittent heating and cooling by episodic accretion is the favored mechanism. In some cases, YSO observations were repeated over shorter timescales, from 0.2 to 2 days. We analyzed these observations to determine whether YSOs exhibited variability over these timescales and, if so, whether it was consistent with the longterm variations that we observed. Results from this study and implications for accretion will be presented.

407.02 – **The Role of Environment in Star Formation**

Dawn E. Peterson[1]

[1]*Harvard-Smithsonian CfA.*

10:20 AM - 10:40 AM

We present preliminary results from a study of a large sample of Bok globules and bright-rimmed clouds (BRCs) that have been observed with the NASA Spitzer Space Telescope. We identify and classify young stellar objects (YSOs) using Spitzer and near-infrared 2MASS photometry, and will present the ratio of Class I to Class II YSOs in each of the regions. In addition, near-infrared extinction maps will be presented. The stellar populations will be used, along with the known gas masses of these clouds to estimate the fraction of the gas from a molecular cloud that typically ends up as stars. The initial conditions for the formation of a single star, binary or cluster of stars can be constrained, and with an estimate of the age from theoretical models, the time it takes a star (or a cluster of stars) to form can also be constrained, as well as the timescales for the various evolutionary states. The Bok globules are unique because they are simple environments, free from the confusing effects of winds and external turbulence that are often seen in young clusters embedded within larger, star-forming complexes. By studying a large number of these simple structures spanning a wide range of evolutionary states, and comparing their properties with those of the more complex BRCs, which are strongly influenced by nearby O and B stars, we can ultimately study the role that environment plays in star formation.

407.03 – **Protostellar Jets and Outflows: New Features from Spitzer Image Analysis**

Thangasamy Velusamy[1], W. D. Langer[1]

[1]*JPL.*

10:40 AM - 10:50 AM

The Spitzer IRAC and MIPS bands offer a unique resource to study a wide range of components simultaneously: protostars; protostellar disks, jets and outflows; protostellar envelopes and cores. In the short wavelength IRAC bands the outflow cones are observable in scattered light from the protostar. Each IRAC band contains several of the H_2 rotational lines, thus the H_2 molecular jets and bow shocks are readily identifiable in all IRAC bands, while the hottest atomic/ionic gases in the jet heads are identifiable in the MIPS 24 micron band which contains a few atomic/ionic emission lines. Here we report the results from our ADAP-sponsored program to study the protostellar jets and outflows in the Spitzer Archive. We use HiRes deconvolution of the Spitzer images to improve the visualization of spatial morphology by enhancing resolution (to sub-arcsec for IRAC bands and 1.8″ for MIPS 24 micron) and by removing the contaminating sidelobes from bright sources. As an example of the result of combining the high sensitivity in Spitzer images and reprocessing with HiRes, we detected the following new jet and outflow features in Cep E: wide angle outflow seen in the scattered light; morphological details of at least 29 jet driven bow shocks; three atomic/ionic line emission features in 24 micron compact features, identified as jet heads; and, a flattened protostellar envelope seen as an 8 micron absorption band against the interstellar background PAH emission. While the IRS H_2 spectral line maps of protostellar jets are very limited, our results show that the IRAC images available in the Spitzer archives have the potential to study the H_2 emission in a large sample of outflow sources. This ADAP-sponsored research was conducted at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration.

407.04 – **Studies of Evolved Star Mass Loss: GRAMS Modeling of Red Supergiant and Asymptotic Giant Branch Stars in the Magellanic Clouds**

Benjamin A. Sargent[1], S. Srinivasan[2], D. Riebel[3], M. Boyer[1], M. Meixner[1]

[1]*Space Telescope Science Institute,* [2]*Institut d'Astrophysique de Paris, France,* [3]*The Johns Hopkins University.*

10:50 AM - 11:00 AM

As proposed in our NASA Astrophysics Data Analysis Program (ADAP) proposal, my colleagues and I are studying mass loss from evolved stars. Such stars lose their own mass in their dying stages, and in their expelled winds they form stardust. To model mass loss from these evolved stars, my colleagues and I have constructed GRAMS: the Grid of Red supergiant and Asymptotic giant branch star ModelS. These GRAMS radiative transfer models are fit to optical through mid-infrared photometry of red supergiant (RSG) stars and asymptotic giant branch (AGB) stars. I will discuss our current studies of mass loss from AGB and RSG stars in the Small Magellanic Cloud (SMC), fitting GRAMS models to the photometry of SMC evolved star candidates identified from the SAGE-SMC (PI: K. Gordon) Spitzer Space Telescope Legacy survey. This work will be briefly compared to similar work we have done for the LMC. I will also discuss Spitzer Infrared Spectrograph (IRS) studies of the dust produced by AGB and RSG stars in the LMC. BAS is grateful for support from the NASA-ADAP grant NNX11AB06G.

407.05 – **Discovering and Characterizing Black Hole X-ray Sources in Extragalactic Globular Clusters**

Stephen E. Zepf[1], M. B. Peacock[1], A. Kundu[2], T. J. Maccarone[3]

[1]*Michigan State Univ.,* [2]*Eureka Scientific,* [3]*Southampton University.*
11:00 AM - 11:20 AM

There are no known black hole X-ray sources in Galactic globular clusters. This could either be due to the small number of Galactic globular clusters combined with a very low formation rate or a very long duty cycle for globular cluster black hole X-ray sources, or a true absence of black holes in globular clusters. Advances in X-ray and optical observations have made it possible to extend the search for black hole X-ray sources to extragalactic globular clusters. In this way, several years ago we discovered this first unambiguous black hole in a globular cluster. ADAP supported studies have allowed us to find several more such black hole systems in extragalactic globular clusters, clearly showing such objects can be formed. They have also allowed us and others to carry out variability and spectroscopic studies in X-rays and the optical to characterize some of these systems. I will discuss the results of some of this work, including those for one of the best studied systems, RZ2109, which appears to require a stellar-mass black hole accreting near or above its Eddington luminosity from a white dwarf donor.

407.06 – **Modeling Accretion Hysteresis in LMC X-3**

Hal J. Cambier[1], D. Smith[1]

[1]*UCSC.*
11:20 AM - 11:30 AM

The X-ray binary LMC X-3 represents a useful, "partially-controlled" experiment in accretion. The primary feeds by Roche-lobe overflow of a main-sequence star in a very circular orbit, our viewing angle does not likely intersect any warps or the flared rim of the disk, and while we typically see a spectrum dominated by a persistent blackbody component, there is still considerable variation in luminosity and the flux in the power-law tail, and occasionally more extreme state transitions.

We infer the innermost disk and coronal mass fluxes in time based on the spectra, and observe quasi-periodic positive pulses in coronal flow followed with some delay by long drops in disk flow (c.f. Smith et al. 2007 ApJ...669.1138S). We find that models where constant total mass supply is split between independent disk and coronal flows at the circularization radius, even if we consider an unobserved outflow, cannot explain the data. We show our latest progress towards an answer using a model that does incorporate mass transfer between disk and corona by coupling a numerically evolved disk to the evaporation/condensation physics of Liu et al. 2007 ApJ...71.695L. (This work is supported through NASA's ADAP program)

408 – Energetic Binary Stars II

Oral Session – Room 18C – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

408.01 – **The Chandra Galactic Bulge Survey**

Robert I. Hynes[1], P. G. Jonker[2], C. G. Bassa[3], G. Nelemans[4], D. Steeghs[5], M. A. P. Torres[2], T. J. Maccarone[6], S. Greiss[5], J. Clem[1], A. Dieball[6], V. J. Mikles[1], C. T. Britt[1], L. Gossen[1], A. C. Collazzi[1], R. Wijnands[7], J. J. M. In't Zand[2], M. Mendez[8], N. Rea[9], E. Kuulkers[10], E. M. Ratti[2], L. M. van Haaften[4], C. Heinke[11], F. Ozel[12], P. J. Groot[4], F. Verbunt[2]

[1]*Louisiana State University,* [2]*SRON, Netherlands Institute for Space Research, Netherlands,* [3]*University of Manchester, United Kingdom,* [4]*Radboud University, Netherlands,* [5]*University of Warwick, United Kingdom,* [6]*University of Southampton, United Kingdom,* [7]*University of Amsterdam, Netherlands,* [8]*University of Groningen, Netherlands,* [9]*Institut de Ciencies de l'Espai (ICE, IEEC-CSIC), Spain,* [10]*ISOC, ESA/ESAC, Spain,* [11]*University of Alberta, Canada,* [12]*University of Arizona.*
10:00 AM - 10:10 AM

The Chandra Galactic Bulge Survey (GBS) is a shallow but wide survey of two approximately 6x1 degree strips of the Galactic Bulge about a degree above and below the plane. The survey by design targets regions where extinction and crowding are manageable and optical counterparts are accessible to detailed follow-up. Our strategy is based on going deep enough to detect quiescent low-mass X-ray binaries (LMXBs), but no deeper in order to avoid an excess of cataclysmic variables (CVs), while covering a large area to maximize the numbers of recovered objects. The primary goals of the GBS are to test predictions of binary evolutionary models through number counts and period distributions of detected sources, and to greatly expand the sample of LMXBs suitable for detailed optical follow-up including mass determination. We have identified 1234 X-ray sources most with optical counterparts, and expect these to be divided evenly between quiescent LMXBs, magnetic CVs, and R CVn stars, with smaller numbers of other source types. We are actively pursuing multiwavelength follow-up including searches for optical, infrared, and ultraviolet counterparts, measurement of variability, and optical spectroscopy. I will summarize the goals of the project and highlight some of the results obtained so far.

This work is supported by the National Science Foundation under Grant No. AST-0908789.

408.02D – **An Infrared Study Of Compact Binary Systems**

Juthika Khargharia[1]

[1]*University of Colorado.*
10:10 AM - 10:30 AM

Compact binaries are interacting binary star systems in which a compact stellar remnant like a black hole or a neutron star accretes material from a main-sequence or slightly evolved star. Accurate masses of the compact object in these systems are important in understanding accretion disk dynamics, binary evolution, winds and jets, and studying physics in the strong gravity regime. Using a combination of infrared spectroscopy and imaging, I have determined accurate compact object masses in a few of these systems. Additionally, I have applied infrared spectroscopy to place important estimates on other system parameters such as the spectral type, radial and rotational velocity of the companion in a compact binary system.

408.03 – **A Radial Velocity Study of Hot Subdwarf B Stars with Cool Main Sequence Companions**

Brad Barlow[1], R. A. Wade[1], S. E. Liss[1], M. A. Stark[2]

[1]*The Pennsylvania State University,* [2]*University of Michigan-Flint.*
10:30 AM - 10:40 AM

Many hot subdwarf B (sdB) stars show composite spectra and energy distributions indicative of G- or K-type main sequence companions. Binary population synthesis (BPS) models demonstrate such systems can be formed by Roche lobe overflow but disagree on whether the resulting orbital periods will be long (years) or short (days). Few studies have been carried out to assess the orbital parameters of these composite binaries; what little observations there are suggest the periods are long. To help address this problem, we selected fifteen moderately-bright (V~13) sdB stars with composite spectra for synoptic radial velocity (RV) monitoring. From January 2005 to July 2008, we acquired between 4 and 14 observations of each target using the bench-mounted Medium Resolution Spectrograph on the Hobby-Eberly Telescope. Cross-correlation techniques were used to measure RVs from the cool companion lines with ~700 m/s precision. Here we present RV measurements and orbital parameter estimates (when appropriate) for all systems in our sample and discuss the constraints they place on BPS models. Preliminary measurements of PG 1701+359, the most well-studied object in our sample, indicate the orbit has neither a short period nor a high velocity amplitude. This material is based upon work supported by the National Science Foundation under Grant No. AST-0908642.

408.04D – **Searching for Flares in Hard X-rays/Soft Gamma Rays with GBM Using the Earth Occultation Technique**

James Rodi[1], A. Camero-Arranz[2], G. Case[1], V. Chaplin[3], M. Cherry[1], M. Finger[2], P. Jenke[4], J. Taylor[1], C. Wilson-Hodge[4]

[1]*Louisiana State University,* [2]*USRA,* [3]*University of Alabama-Huntsville,* [4]*NASA Marshall Space Flight Center.*
10:40 AM - 11:00 AM

Employing the NaI detectors of the Gamma-ray Burst Monitor (GBM) onboard NASA's Fermi satellite, fluxes of hard x-ray/soft gamma-ray sources can be measured by using the Earth Occultation Technique (EOT). EOT uses the step-like features in the detector count rate caused by a source passing into or out of occultation by the Earth to derive fluxes. GBM's large field of view allows for all-sky monitoring of sources at energies from 8 keV to ~ 1 MeV. Because of the extreme variability of the sky at these energies, the ability to observe the sky in the hard x-ray/soft gamma-ray regime is important. While there are presently two other all-sky monitors that observe in the hard x-rays, the Monitor of All-sky X-ray Imaging (MAXI) on the International Space Station and the Burst Alert Telescope (BAT) on the Swift satellite, but only GBM has the capability to observe sources at soft gamma-ray energies. Here we present results from a search for transient events from sources in the GBM EOT catalog from the first 3 years of operation of Fermi.

408.05 – **The X-ray Point Source Population of NGC 300**

Breanna A. Binder[1], B. F. Williams[1], S. F. Anderson[1], J. J. Dalcanton[1], M. Eracleous[2], T. J. Gaetz[3], M. R. Garcia[3], A. K. H. Kong[4], P. P. Plucinsky[3], A. C. Seth[3], E. D. Skillman[5], D. R. Weisz[1]

[1]*University of Washington,* [2]*Pennsylvania State University,* [3]*Harvard-Smithsonian Center for Astrophysics,* [4]*National Tsing Hua University, Taiwan,* [5]*University of Minnesota.*
11:00 AM - 11:10 AM

NGC 300 was observed by the Chandra X-ray Observatory on 24 Sept. 2010 for 63 ks

as part of the Chandra Local Volume Survey. Roughly one hundred highly significant X-ray point sources were detected down to a limiting luminosity of ~10^{35} erg/s, including high- and low-mass X-ray binaries, supernova remnants, and background AGN. Many of these X-ray sources have been tentatively classified using X-ray color-color diagrams, spectral modeling, and temporal variability analysis. We have additionally examined the radial source distribution and X-ray luminosity function of NGC 300. The high quality of our Chandra X-ray data has enabled us to perform a detailed study of the X-ray emission associated with the SN 2010da outburst (a suspected high mass X-ray binary) and the Wolf-Rayet + black hole binary NGC 300 X-1. This work has been supported by Chandra grant GO1-12118X.

409 – Galactic Centers

Oral Session – Room 16A – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

409.01 – **GBT Measurements of the Physical Properties of the Sgr B2 Region**

Glen Langston[1], D. R. Schmidt[2], K. Christiansen[3]

[1]NRAO, [2]Franklin and Marshall, [3]Rochester Institute of Technology.

10:00 AM - 10:10 AM

We present NRAO GBT observations of ammonia 1-1 and 2-2 emission in the Sgr B2 region, in order to estimate the physical temperature of this region. The observations were made with the 7-beam K-band Focal Plane Array (KFPA) collecting spectra over a 11' by 9' region.

We compare these observations with molecular line spectra obtained with the GBT in the frequency range 12.4 to 15.0 GHz. In this frequency range, Hydrogen α, β, and γ recombination lines, Helium α recombination lines and emission from the **SO** molecule are detected. Molecular absorption lines from **OH**, **H_2CO** and **CH_3CO** are detected at velocity 62±3 km/sec. Measurements of the line widths and intensities are presented for the central region of Sgr B2.

409.02 – **Sgr A*: Energizing the Surroundings across Epochs**

Roman Shcherbakov[1], F. Baganoff[2], R. Penna[3], J. McKinney[4]

[1]University of Maryland, [2]MIT, [3]Harvard University, [4]Stanford.

10:10 AM - 10:20 AM

The Galactic Center hosts a supermassive black hole (BH) with likely a large spin a~0.9. When it accretes at a high rate, the BH should produce strong radiative and mechanical output energizing the surroundings. Currently, only 0.01% of available ejected stellar winds accretes onto the BH likely due to the feedback by conduction. Starved BH is in an underluminous state. I will show how the effective cooling and suppression of conduction may readily lead to 10^4 times larger accretion rate, at which Sgr A* is powerful again. Correspondent periods of jet/accretion disk formation and destruction can be as short 1000 years, but recur multiple times. Such episodes can be responsible for both the light echo in Sgr B and the Fermi bubbles.

409.03D – **Direct Orbital Parameter Estimates of the Young Stellar Disk in the Galactic Center**

Sylvana Yelda[1], A. M. Ghez[1], J. R. Lu[2], T. Do[3], L. Meyer[1], M. R. Morris[1], K. Matthews[4]

[1]UCLA, [2]Institute for Astronomy, Hawaii, [3]UC Irvine, [4]Caltech.

10:20 AM - 10:40 AM

The Galactic center (GC) contains both a supermassive black hole (SMBH) and a collection of young, massive WR/O stars, a seemingly paradoxical combination given our current knowledge of star formation. Approximately half of these young stars orbit the black hole in a coherent, clockwise stellar disk. The dynamics of this young population can be used to constrain theories of star formation in the hostile environment of a SMBH. We present high-precision astrometry (~0.1 mas) of ~100 young stars obtained with the Keck telescopes over 16 years, including six years of Laser Guide Star Adaptive Optics imaging and spectroscopy. We have extended the radial range of our data set by a factor of three over our previous efforts and detect a single disk of young stars. We have also increased the number of plane-of-the-sky acceleration measurements beyond the central arcsecond by a factor of ~10 and as far out as 1.5" (~0.06 pc), the furthest from the SMBH to date for these young stars. Such measurements allow us to directly estimate stellar orbital parameters, including eccentricities, without making a priori assumptions about disk membership, as has been done in the past. We find no evidence for a bimodal eccentricity distribution. Furthermore, seven of the WR/O stars have eccentricities > 0.2, while many others have eccentricity lower limits of 0.2. This finding renders in situ star formation in a circular disk with a normal IMF around the SMBH unlikely.

409.04 – **HST Observations of the Stellar Distribution Near Sgr A***

Howard A. Bushouse[1], F. Yusef-Zadeh[2], M. Wardle[3]

[1]STScI, [2]Northwestern University, [3]Macquarie University, Australia.

10:40 AM - 10:50 AM

The Milky Way nuclear cluster, in which Sgr A* is embedded, consists of a mixture of evolved and young stellar populations. We present an HST/NICMOS study of the distribution of stellar light within the inner 10" of the Galactic Center. We measure the radial surface brightness distribution surrounding Sgr A* in three near-infrared imaging bands and compare the resulting distribution with previous studies involving a range of different techniques. Our analysis shows that the surface brightness profile within 5" or 0.2 pc of Sgr A* can be fitted with broken power laws, with slopes of -0.13 (r < 0.7") and -0.34 (r > 0.7"). This is consistent with previous measurements, in that the profile becomes shallower at small radii. Modeling of the surface brightness profile gives a stellar density that increases roughly as 1/r within the inner 1" of Sgr A*. This slope is not consistent with that expected for an old, dynamically-relaxed cluster surrounding a black hole. It is also in contrast to some previous studies that had shown evidence for a decline in the number density of stars very near Sgr A*.

409.05 – **Sgr A*: Quiescent But Not Atypical -- A Comparison With A0620-00**

Sera Markoff[1], M. A. Nowak[2], J. Nip[1], F. K. Baganoff[2], C. S. Froning[3], A. G. Cantrell[4], T. J. Maccarone[5], E. Gallo[6]

[1]API, University of Amsterdam, Netherlands, [2]MIT Kavli Institute for Astrophysics & Space Research, [3]CASA, University of Colorado, [4]Department of Astronomy, Yale University, [5]School of Physics & Astronomy, University of Southampton, United Kingdom, [6]Department of Astronomy, University of Michigan.

10:50 AM - 11:00 AM

Sgr A* is the weakest accreting black hole we have ever observed, yet it is not a particularly unique object. We know that the majority of galaxies are more like Sgr A* than active galactic nuclei (AGN), so it is important to understand what these low-level engines can contribute to their environs. The Fundamental Plane of Black Hole Accretion is an important tool for making comparisons of black hole physics across the mass scale. In this talk, I will present the first ever joint fits between Sgr A* in the flaring state and the stellar-mass quiescent black hole X-ray binary, A0620-00. I will show how the same physical model with exactly the same (mass scaled) parameters can apply to both sources, and discuss what this could mean for our understanding of both objects individually. This new method can help break degeneracies between models, and for these sources in particular shed light on questions of particle acceleration at the lowest accretion rates.

409.06 – **Keck AO Observations of the Central 5 pc of M31**

Jessica R. Lu[1], R. M. Rich[2], A. M. Ghez[2], K. Matthews[3], K. Gebhardt[4]

[1]IfA, U. of Hawaii, [2]UCLA, [3]Caltech, [4]University of Texas, Austin.

11:00 AM - 11:10 AM

The neighboring Andromeda galaxy (M31) harbors both a supermassive black hole and an apparent 200 Myr starburst cluster within the central parsec. Since the nucleus of M31 has relatively little molecular gas, the source of gas for this recent star formation event has not yet been determined. One proposed solution is that an eccentric disk of old stars, observed to extend a few parsecs from the black hole, is both the source of the molecular gas and the means for transporting the gas inward. We present results from new Keck adaptive optics spatially resolved spectroscopy of the entire eccentric disk and central parsec. We have mapped the 2D kinematics in this region in order to measure the dynamical structure of the eccentric disk and determine if it is precessing slowly enough for gas on self-intersecting orbits to shock, cool, and plunge into the central parsec to fuel future starbursts or black hole accretion.

410 – Surveys and Large Programs II

Oral Session – Room 18B – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

410.01 – **Science Quality Mosaics and a Source List for the Spitzer Heritage Archive**

Peter L. Capak[1], H. Teplitz[2], D. Hanish[2], Spitzer Science Center, T. Brooke[2], R. Laher[3]

[1]Caltech, [2]IPAC/Caltech, [3]IPAC.

10:00 AM - 10:10 AM

The Spitzer Science Center has produced science quality mosaics and a compact source list for the majority of data taken with the Spitzer Space Telescope using the IRAC instrument and the 24um channel on the MIPS instrument. These products cover >1000

square degrees on the sky and enable a wide array of science. I will give a brief overview of the source list and some early galactic and extragalactic science enabled by it.

410.02 – **The JCMT Legacy Survey: A Spectroscopic And Continuum Survey Of The Submillimetre Sky**

Antonio Chrysostomou[1], G. R. Davis[1], JCMT Legacy Survey coordinators

[1]*Joint Astronomy Centre.*

10:10 AM - 10:20 AM

A comprehensive survey of the submillimetre sky is underway at the James Clerk Maxwell Telescope (JCMT) using two state-of-the-art instruments: SCUBA-2 is a 10,000 pixel bolometer array, operating simultaneously at 450 and 850 microns (see companion paper: Davis et al. Session 38), and HARP is a heterodyne array receiver operating between 325 and 375 GHz. The JCMT Legacy Survey (JLS) is comprised of 7 survey projects, and ranges in scope from the study of nearby debris disk systems, the study of star formation in nearby molecular cloud systems and more distant structures in our Galactic Plane, to the structure and composition of galaxies in our local neighborhood and the number and evolution of submillimetre galaxies at high redshifts in the early Universe.

The HARP components of the JLS are now complete and with on-sky commissioning of SCUBA-2 at the JCMT recently completed, the continuum component with SCUBA-2 has commenced. In this presentation I will describe the JLS and its constituent projects and also present some of the latest results to emerge from the JLS, including some of the latest data with SCUBA-2.

410.03D – **The Arecibo Zone of Avoidance Survey: First Results**

Travis P. McIntyre[1], R. Minchin[2], P. Henning[1]

[1]*The University of New Mexico,* [2]*Arecibo Observatory.*

10:20 AM - 10:40 AM

The Arecibo L-Band Feed Array Zone of Avoidance Survey (ALFA ZOA) searches for neutral hydrogen gas in galaxies behind the Milky Way. Observations are complete for the shallow portion of the survey and the catalog of detections has been compiled. Many of these detections are new discoveries and some of these are within several megaparsecs of the Local Group. I will present the ALFA ZOA catalog and first analysis and give an update on the status of the rest of the survey. This work was supported by the New Mexico Space Grant and the Cornell University - Arecibo Observatory Predoctoral Fellowship.

410.04 – **Early APOGEE Chemical Results for the Milky Way Bulge**

Ana Elia Garcia Perez[1], C. Allende Prieto[2], D. Bizyaev[3], P. Frinchaboy[4], J. Holtzman[5], J. Johnson[6], S. R. Majewski[1], D. Nidever[1], R. Schiavon[7], M. Schultheis[8], M. D. Shetrone[9], M. Skrutskie[1], J. C. Wilson[1], G. Zasowski[1]

[1]*University of Virginia,* [2]*Instituto de Atrofisica de Canarias, Spain,* [3]*Apache Point Observatory,* [4]*Texas Christian University,* [5]*New Mexico State University,* [6]*Ohio State University,* [7]*Geminy Observatory,* [8]*Observatoire de Besançon, France,* [9]*University of Texas.*

10:40 AM - 10:50 AM

The stellar content of the bulge of the Galaxy is not well characterized yet, in part due to the high extinction and, therefore, limited access at optical wavelengths. The SDSS-III Apache Point Observatory Galaxy Evolution Experiment (APOGEE) is an on-going near-infrared survey acquiring very high quality spectra (S/N > 100 per pixel, R~22,500) of ~100,000 giant stars across the Galaxy. The APOGEE survey will enable a detailed exploration of parts of the bulge that are not chemically well known. We will show preliminary results of the composition of bulge stars collected in the first months of the survey. Metallicity distributions will be presented for different bulge fields and compared with results from the literature, where available.

410.05 – **Exploring The Sagittarius Dwarf Spheroidal Galaxy And Its Tidal Tails With APOGEE**

Steven R. Majewski[1], C. Allende-Prieto[2], T. C. Beers[3], D. M. Bizyaev[4], P. M. Frinchaboy[5], A. Garcia-Perez[1], J. Holtzman[6], I. I. Ivans[7], D. R. Law[8], D. L. Nidever[1], R. P. Schiavon[9], M. Shetrone[10], M. F. Skrutskie[1], J. C. Wilson[1], G. Zasowski[1]

[1]*Univ. of Virginia,* [2]*IAC, Spain,* [3]*JINA/NOAO,* [4]*APO,* [5]*TCU,* [6]*NMSU,* [7]*Univ. of Utah,* [8]*Univ. of Toronto, Canada,* [9]*Gemini Observatory,* [10]*Univ. of Texas.*

10:50 AM - 11:10 AM

The Apache Point Observatory Galactic Evolution Experiment (APOGEE), part of the Sloan Digital Sky Survey III, is exploring the stellar populations of the Milky Way using the Sloan 2.5-m telescope linked to a high resolution (R ~ 22,500), near-infrared (1.51-1.68 microns) spectrograph with 300 optical fibers. For about 100,000, predominantly red giant branch stars that APOGEE is targeting across the Galactic bulge, disks and halo, the collected high S/N (>100 per Nyquist-limit-sized pixel) spectra will provide accurate (+/-200 m/s) radial velocities, stellar atmospheric parameters, and precise (+/- ~0.1 dex) chemical abundances for about 15 chemical species. The APOGEE survey targeting plan includes fields that have been specifically placed on either the core or tails of the Sagittarius (Sgr) dSph galaxy. Some of the target selection has relied on known or suspected giant star members of Sgr identified in previous surveys. But other fields in the path of the Sgr stream serendipitously uncover additional Sgr stars through the normal APOGEE giant star targeting. We report on early results from APOGEE commissioning data that include dozens of Sgr stars spread over several distinct pointings on the Sgr core. In addition, we report the discovery of Sgr stars found in several pointings directed at the Galactic bulge and midplane. These data for Sgr stars lying behind some of the dustiest parts of the Milky Way yield accurate velocities, velocity dispersions and chemical information on stretches of the Sagittarius stream never before explored. The results can be used to refine models of the chemodynamical evolution of the Sgr system and the shape of the gravitational potential of the Milky Way.

410.06 – **First APOGEE Results on Galactic Bulge Kinematics**

David L. Nidever[1], C. Allende Prieto[2], D. Bizyaev[3], P. M. Frinchaboy[4], A. E. Garcia Perez[1], J. Holtzman[5], S. R. Majewski[1], R. Schiavon[6], M. F. Skrutskie[1], G. Zasowski[1]

[1]*Univ. of Virginia,* [2]*Instituto de Astrofisica de Canarias, Spain,* [3]*Apache Point Observatory,* [4]*Texas Christian University,* [5]*New Mexico State University,* [6]*Gemini Observatory.*

11:10 AM - 11:20 AM

The SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE) will obtain high resolution (R~22,500) and high S/N (~100 per pixel) H-band spectra of 100,000 giant stars in the Milky Way disk, bulge and halo to study the chemical and kinematical evolution of the Milky Way Galaxy. APOGEE will be able to probe deep into regions of our galaxy that were previously hidden by a thick veil of dust. I will present first APOGEE results on the Galactic bulge kinematics using commissioning data in 18 fields. Our reduction pipeline currently delivers radial velocites with accuracies of 0.2 km/s for the majority of our target stars. These RVs are used to derive accurate rotation curves and velocity dispersion profiles for our bulge fields, many of them in regions not previously probed. We compare our results to other surveys and to N-body models and confirm that the bulge is dominated by a bar to large longitudes. We also find the first evidence for kinematical substructure in our bulge fields.

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411 – Evolution of Galaxies VII

Oral Session – Room 19A – Thursday, January 12, 2012, 10:00 AM - 11:30 AM

411.01 – **The Properties Of The Stellar Nuclei With The Host Galaxy Morphology In The ACSVCS**

Hyun-chul Lee[1]

[1]*The University of Texas - Pan American.*

10:00 AM - 10:10 AM

We have revisited the ACS Virgo Cluster Survey (ACSVCS), a Hubble Space Telescope program to obtain ACS/WFC g and z bands imaging for a sample of 100 early-type galaxies in the Virgo Cluster. In this study, we examine 51 nucleated early-type galaxies in the ACSVCS in order to look into the relationship between the photometric and structural properties of stellar nuclei and their host galaxies. We morphologically dissect galaxies into five classes. We note that (1) the stellar nuclei of dwarf early-type galaxies (dS0, dE, and dE,N) are generally fainter and bluer with g > 18.95 and (g-z) < 1.40 compared to some brighter and redder counterparts of the ellipticals (E) and lenticular galaxies (S0), (2) the g-band half-light radii of stellar nuclei of all dwarf early-type galaxies (dS0, dE, and dE,N) are smaller than 20 pc and their average is about 4 pc, and (3) the colors of red stellar nuclei with (g-z) > 1.40 in bright ellipticals and lenticular galaxies are bluer than their host galaxies colors. We also show that most of the unusually RED stellar nuclei with (g-z) > 1.54 in the ACSVCS are the central parts of bright ellipticals and lenticular galaxies.

411.02D – **Kinematics and Energetics in Local Luminous Infrared Galaxies**

Vivian U[1], D. B. Sanders[1], GOALS Team

[1]*UH Institute for Astronomy.*

10:10 AM - 10:30 AM

In the present paradigm of the merger-driven galaxy evolution scenario, gas-rich spirals interact and merge, triggering intense star formation and nuclear activity that can deplete the gas in progenitors of giant ellipticals. Starburst and AGN activities in systems like these cause an infrared-luminous stage associated with enhanced star formation rate and black hole growth. Therefore, the local luminous and ultraluminous infrared galaxies ((U)LIRGs) provide the ideal nearby, extreme environments in which we study black

hole accretion, AGN feeding and feedback, and the nature of star formation in starbursts, the connection among which remains poorly understood due to limitations of previous instrumentation.

Our new high-resolution submillimeter and near-infrared integral-field data cube of the nuclei in (U)LIRGs taken with the Submillimeter Array (SMA) and the Keck Telescopes reveal circumnuclear gas kinematics at an unprecedented level of details. At the distances of these local mergers, our SMA long-baseline and Keck laser guide star adaptive optics observations probe the physical conditions of the centers of these systems at the scale of ~50-200 pc. For instance, the molecular gas emission in between the two AGNs in NGC 6240 has been resolved into two peaks that may be consistent with a scenario where two pre-coalescence gas disks are interacting at an angle; near-infrared integral-field spectra of the two nuclei in Mrk 273 disclose the temperature and excitation mechanism around an AGN and the nuclear disk of a potential second AGN. These findings give a detailed description of the molecular gas kinematics as well as AGN/starburst activities in the central dusty region of these merging systems, and paint an overall picture of the evolution of the energetics in (U)LIRGs as the merger sequence progresses.

VU would like to acknowledge partial funding support from the NASA Harriet G. Jenkins Predoctoral Fellowship Project.

411.03 – **The Properties of IRAS Detected Mergers in the Local Universe**

Alfredo Carpineti[1], S. Kaviraj[1], D. L. Clements[1], D. Darg[2], A. K. Hyde[1], C. Lintott[2]

[1]Imperial College, United Kingdom, [2]Oxford University, United Kingdom.

10:30 AM - 10:40 AM

Galaxy merging is a fundamental aspect of the standard hierarchical galaxy formation paradigm. We have used a large, homogeneous set of nearby mergers, selected through direct visual inspection of the entire SDSS using the GalaxyZoo project, to perform the first blind far-infrared (FIR) study of the local merger population. 3300+ mergers were cross-matched with the Imperial IRAS-FSC Redshift Catalogue, resulting in 606 FIR detections. The IRAS- detected mergers are typically more massive, with smaller separations, weaker tidal forces and bluer colours than their undetected counterparts. The IRAS-detected mergers are mostly (98%) spiral-spiral systems, with a median FIR luminosity of 10^{11} LSun and a median star-formation rate of around 15 MSun per year. They reside in low density environments but we find no dependence between group richness and their infrared properties. Their SFR seems to depend on the total mass of the system with little dependence on the mass ratio. Optical emission line ratios indicate that the AGN fraction increases with increasing FIR luminosity with a dramatic increase in the members that are ULIRGs . Comparing the typical separations of mergers that are LIRGs and those that are ULIRGs we estimate the timescale for this transition and find a value of (50 ± 16) Myr .

411.04D – **Observational Studies of Interacting Galaxies and the Development of a Wide Integral-field Infrared Spectrograph**

Richard C. Chou[1]

[1]University of Toronto, Canada.

10:40 AM - 11:00 AM

Interacting galaxies are thought to be the essential building blocks of elliptical galaxies under the hierarchical galaxy formation scenario. The goal of my dissertation is to broaden our understanding of galaxy merger evolution through both observational studies and instrumentation development. Observationally, photometric studies conducted in this dissertation better constrain wet and dry merger density evolution up to z~1 using the five CFHTLS broad band photometry. I have discovered that the most massive ellipticals may not be formed via merging processes, unless the merging timescale is much longer than the expected value. Spectroscopically, kinematic study of close pair galaxies shows that red close pairs tend to live in more massive galactic haloes, which supports the gravitational star formation quenching mechanism proposed by the hot halo model. Further constraining the details of galactic color transformations requires careful analyses of 2D spectra from integral-field spectroscopy with wide field of views, which can provide uniform 2D spectroscopic information of merging galaxies.

However, the currently available near-infrared integral field spectrographs cannot provide both wide field of view and high spectral resolution. Thus, I undertook the optical design of a wide integral field infrared spectrograph (WIFIS) that can provide an unprecedented 5" x 12" field of view on a 10-m class telescope. This WIFIS design has a high spectral resolution of 5000, covering each of J, H, Ks band in a single exposure, and is optimized for studying mergers at redshift z => 1. In addition to this design, to study mergers at relatively low redshifts of z = 0.4 to 1, I also developed another optical design of WIFIS covering shorter wavelengths of z,J,H bands. I am presently working on the alignment and characterization of WIFIS in order to have first light in Fall 2012.

411.05 – **A Complete Census of Cold Gas and Dust in Nearby Luminous Infrared Galaxies**

Sabrina Stierwalt[1], D. Frayer[2], D. Windemuth[3], R. Maddalena[2]

[1]Caltech, [2]NRAO, [3]Wesleyan University.

11:00 AM - 11:10 AM

We present the results of a multiwavelength study to take a complete census of cold dust, molecular gas, and neutral hydrogen in the nearby luminous and ultraluminous infrared galaxies ((U)LIRGs) from the Great Observatories All-sky LIRG Survey (GOALS) derived from the IRAS Revised Bright Galaxy Sample. The 182 LIRG and 20 ULIRG systems span a range of merger stages, spectral types, and, as an IR-selected sample, a range of extinction measures. For a significant subset (~125 systems) we have obtained global 21-cm and new+archival CO measurements and find as L(IR) increases, the neutral gas fraction decreases more steeply than the total (neutral+molecular) gas fraction. The global measurements allow us to trace gas fractions and star formation efficiencies throughout the merging process.

411.06 – **The Evolution Of The Galaxy Mass-size Relation In Different Environments**

Simona Mei[1], A. Raichoor[2], A. S. Stanford[3], B. P. Holden[4], F. Nakata[5], P. Rosati[6], F. Shankar[7], M. Tanaka[8], H. C. Ford[9], M. Huertas-Company[10], G. D. Illingworth[4], T. Kodama[11], M. Postman[12], A. Rettura[13], J. P. Blakeslee[14], R. Demarco[15], M. J. Jee[3], W. Rick[12]

[1]Observatory of Paris/University P. Diderot - IPAC Caltech, [2]Osservatorio Astronomico di Brera, Italy, [3]University of California Davis, [4]University of Santa Cruz, [5]Subaru Telescope, National Astronomical Observatory of Japan, Japan, [6]ESO, Germany, [7]Observatory of Paris, France, [8]IPMU, University of Tokyo, Japan, [9]Johns Hopkins University, [10]Observatory of Paris/University P. Diderot, France, [11]National Astronomical Observatory of Japan, Japan, [12]Space Telescope Science Institute, [13]University of California Riverside, [14]Herzberg Institute of Astrophysics, Canada, [15]Universidad de Concepcion, Chile.

11:10 AM - 11:20 AM

We present our recent results on the evolution of the galaxy mass-size relation in different environments at z~1.3, for different morphological types and galaxy masses between 10^{10} M_{Sun} and $10^{11}.5$ M_{Sun}. We find that results on the evolution of the mass-size relation depend on how galaxies are morphologically selected (visually or by their Sersic index). When we select early-type galaxies (ETG) by visual morphology, the field mass-size relation does not show significant evolution from z~1.3 to the present (interestingly, in contrast from what is observed at higher masses). In clusters, the ETG mass-size relation at z~1.3 is shifted towards lower sizes on average. In the denser environment, either ETGs sizes have evolved on average to twice their size, or more ETGs have been formed from non ETG progenitors or larger galaxies have been accreted to a pristine compact population. The late-type mass-size relation does not show significant overall evolution in any environment.

411.07 – **First Results from TYPHOON: A Spectrophotometric Data Cube Program**

Laura Sturch[1], B. Madore[2]

[1]Boston University, [2]Carnegie Observatories.

11:20 AM - 11:30 AM

TYPHOON is a program for producing and analyzing spectrophotometric data cubes with unprecedented resolution and coverage. This program has wavelength coverage spanning 3727 to 7000 Angstroms, has a 2-6 Angstrom spectral resolution, a 15 arcmin spatial field, is seeing limited to < 1 arcsec, and is being employed on the 100" duPont telescope in Las Campanas. TYPHOON uses instruments already active on the telescope and thus is well underway. Using TYPHOON, we can analyze kinetic structure, view 3D representations of galaxies in wavelength space, create integrated spectra of bars, nuclei, rings, etc, and analyze galactic population synthesis. TYPHOON is a powerful tool for extragalactic science with many applications.

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412 – White Dwarf Stars From the Telescope to the Laboratory and Back Again: Exploring Extreme Physics

Invited Session – Ballroom D – Thursday, January 12, 2012, 11:40 AM - 12:30 PM

412.01 – **White Dwarf Stars From the Telescope to the Laboratory and Back Again: Exploring Extreme Physics**

Donald E. Winget[1]

[1]University of Texas.

11:40 AM - 12:30 PM

Astronomy, in contrast with other sciences, has traditionally been considered an

observational science; it has not been possible to perform experiments on the objects we observe. This situation has changed in a way that is transformational. Although laboratory astrophysics has long been an important part of astronomical research, what has changed is the ability to produce large enough chunks of a star that we can make measurements and perform experiments. We are now able to make *macroscopic* quantities of star stuff in the lab: plasmas created under conditions that are the same as the plasmas in stars. In a cosmic sense, as physicist Greg Rochau likes to point out, the conditions on Earth are far from normal, they could even be considered extreme or bizarre compared to the more cosmically normal conditions in stars. We can now examine, on Earth, matter under more cosmically "normal" conditions.

I will describe how this came about, the technology behind it, and the results of our recent laboratory experiments done on Z at Sandia National Laboratories. We will discuss how this will change our understanding of white dwarf stars and, through this, what we know about the universe and its contents based on these stars.

Finally, we will briefly examine other fundamental astrophysics being done on Z and focus on the tremendous potential of the Z platform for astrophysics experiments in the future.

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413 – Instrumentation: Ground Based

Oral Session – Room 17B – Thursday, January 12, 2012, 2:00 PM - 3:30 PM

413.01 – **Early Results from the Long Wavelength Array**

Gregory B. Taylor[1], LWA Collaboration

[1]*Univ. of New Mexico.*

2:00 PM - 2:10 PM

The Long Wavelength Array (LWA) will be a new multi-purpose radio telescope operating in the frequency range 10-88 MHz. Scientific programs include pulsars, supernova remnants, general transient searches, radio recombination lines, solar and Jupiter bursts, investigations into the "dark ages" using redshifted hydrogen, and ionospheric phenomena. Upon completion, LWA will consist of 53 phased array "stations" distributed accross a region over 400 km in diameter. Each station consists of 256 pairs of dipole-type antennas whose signals are formed into beams, with outputs transported to a central location for high-resolution aperture synthesis imaging. The resulting image sensitivity is estimated to be a few mJy (5sigma, 8 MHz, 2 polarizations, 1 h, zenith) from 20-80 MHz; with angular resolution of a few arcseconds. Additional information is online at http://lwa.unm.edu. Partners in the LWA project include LANL, JPL, NRAO, NRL, UNM, NMT, and Virginia Tech. The first station of the LWA, called "LWA1", is located near the center of the EVLA and has recently begun scientific operations. The LWA1 images the sky in realtime using the "transient buffer - narrowband" (TBN) system which is operational with 257 dipoles, and a bandwidth of 70 kHz. The LWA1 can also form up to 4 beams on the sky simultaneously with 16 MHz bandwidth in each of two tuning and full polarization. Early results include observations of pulsars, the Sun, and Jupiter.

413.02 – **Commissioning the First Station of the Long Wavelength Array**

Jayce Dowell[1], LWA Collaboration

[1]*University of New Mexico.*

2:10 PM - 2:20 PM

The Long Wavelength Array (LWA, http://lwa.unm.edu/) is a low frequency array operating between 10 and 88 MHz being constructed in New Mexico, USA. The first station of the LWA, LWA-1, consists of 256 dual polarization dipoles that can be sampled independently or combined together into four electronically steerable beams. A second station, LWA-2, is also being constructed and currently consists of 20 dual polarization dipoles. I will discuss the current status of commissioning the instrument and show early results from both stations.

I will also provide an overview of the LWA Software Library (LSL, http://fornax.phys.unm.edu/lwa/trac/wiki) that is being developed. LSL is a general purpose Python module that runs on Linux and Mac OSX platforms. The library provides a variety of visualization and analysis tools for the various LWA data products. Some of the tasks which users can accomplish within the LSL framework include working with LWA data in the time or frequency domain, identifying RFI, forming images, and applying incoherent de-dispersion to pulsar data. LSL also provides facilities for converting the LWA data products into forms readable by other popular analysis packages.

413.03D – **The Search for Ionospheric Effects at 150 MHz with PAPER**

Nicole E. Gugliucci[1], R. Bradley[2], PAPER Collaboration

[1]*Univ. of Virginia,* [2]*National Radio Astronomy Observatory.*

2:20 PM - 2:40 PM

PAPER (the Precision Array to Probe the Epoch of Reionization) is a telescope designed to detect the redshifted hydrogen signal from the early universe. The hydrogen is at a redshift of approximately 6-14, bringing the spin-flip transition of neutral hydrogen from 1.4 GHz to a regime between 100 and 230 GHz. PAPER has a test site with 32 antennas in the Radio Quiet Zone of Green Bank, West Virginia, and a 64-antenna array at the Square Kilometer Array candidate site in the Karoo, South Africa.

Astronomical observations at such low frequencies are made more challenging by the refractive properties of the ionosphere. We present the angular shifts in bright source positions (Cyg A, Cas A, Vir A, and Tau A) as probes of the variations in the total electron content (TEC) along the lines of sight between the sources and the 32-element array in Green Bank. With an integration time of 10 seconds, we can probe for the small fluctuations, using the visibilities, that may be the most difficult to calibrate in upcoming experiments and observations. More sensitive probes of longer timescales are also done by imaging the sky with both the 32 and 64-element arrays. Here again, the bright source position stability is used as an indicator of the TEC stability. The wideband nature of the PAPER instrument enables it to probe the effects of a varying TEC over a nearly 100 MHz bandwidth. We compare these measurements to more traditional methods of probing the ionosphere, such as GPS satellites, and we discuss the implications that these measurements will have on experiments aimed at detecting the epoch of reionization.

413.04D – **The Subaru Coronagraphic Extrem Ao: Near Diffraction Limit Visible Imageron A 8m Meter Telescope.**

Vincent Garrel[1], O. guyon[1], P. baudoz[2], F. martinache[1]

[1]*Subaru Telescope, NAOJ,* [2]*Observatoire de Paris, LESIA, France.*

2:40 PM - 3:00 PM

The Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) system is an instrument originally designed as a significant upgrade of the coronagraphic and AO correction capacity for the current infrared HiCIAO imager in order to greatly improve its image contrast in the very close (less than 0.5") neighborhood of stars. Next to its infrared coronagraphic path, a visible path has been implemented, composed of an high-order wavefront sensor and a dual wavelength visible science imager. The visible science imager relies on the capacity of two identical synchronized EMCCD cameras, offering photocounting ability. Benefiting from both adaptive optics correction and new data processing techniques, the visible imager is a powerful tool for high angular resolution imaging and opens numerous new science opportunities. We propose here a new image processing algorithm, based on the selection of the best signal for each spatial frequency. A factor 2 to 3 in Strehl ratio is obtained compared to the AO long exposure time depending on the image processing algorithm used and the seeing conditions. The system is able to deliver close to diffraction limited images at 650nm. Based on first on-sky results, we also demonstrate that this approach offers significantly better results than the classical lucky imaging approach while being simpler than other speckle interferometry techniques.

413.05 – **The Dark Energy Survey & Camera (DECam)**

H. Thomas Diehl[1], Dark Energy Survey Collaboration

[1]*Fermi National Accelerator Laboratory.*

3:00 PM - 3:10 PM

The Dark Energy Survey (DES) is a next generation optical survey aimed at understanding the 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 is building the Dark Energy Camera (DECam), a 3 square degree, 570 Megapixel CCD camera that will be mounted at the prime focus of the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory. CCD production has finished, yielding roughly twice the required 62 2kx4k detectors. The construction of DECam is finished. Integration and commissioning on a "telescope simulator" of the major hardware and software components, except for the optics has concluded at Fermilab. Final assembly of the optical corrector is underway at University College, London. Most components have already been received at CTIO, where installation has started. "First-light" will be in May or June 2012. This oral presentation will describe DES and the technical design and status of DECam.

413.06 – **First Optical Observations with Microwave Kinetic Inductance Detectors**

Seth Meeker[1], B. A. Mazin[1], K. O'Brien[1], S. McHugh[1], B. Bumble[2], E. Langman[1], M. Navaroli[1]

[1]*UCSB Department of Physics,* [2]*NASA Jet Propulsion Labratory.*

3:10 PM - 3:20 PM

In July 2011 the ARray Camera for Optical to Near-IR Spectrophotometry (ARCONS) was successfully deployed at the Palomar 200" Hale telescope for its first-light run. This photon counting integral field unit (IFU) is the first instrument to utilize Microwave Kinetic Inductance Detectors (MKIDs) for optical to near-IR astronomy. MKIDs are an emerging low temperature detector (LTD) technology with potential applications from sub-millimeter to X-ray astronomy. ARCONS houses a 1024 (32x32) pixel MKID array, making ARCONS not only the first optical/near-IR MKID camera, but the largest

non-dispersive optical/near-IR spectrophotometer by a factor of 10. The camera has a spectral resolution of R~12 at 400 nm, and is capable of time-tagging individual photons with microsecond resolution. Its operational bandwidth is 400 to 1100 nm, which is limited mostly by the optics necessary to reduce sky counts in the near-IR. ARCONS was deployed at Palomar's Coudé focus with a field of view of 7.5"x7.5" (.23"x.23" per pixel). In this talk I will discuss the performance of the instrument through observations of photometric standard stars and other calibration sources. Early science results will also be shown, including observations of the Crab Pulsar and Einstein's cross. Having proven the viability of MKID technology in the optical to near-IR regime, we can now build on its potential to image fainter and more challenging targets such as millisecond pulsars.

413.07 – **Results of Recommissioning FLAMINGOS-2**

Percy L. Gomez[1], R. Diaz[1], P. Pessev[1], P. Prado[1], P. Candia[1], E. Hogan[1], G. Perez[1], M. Lazo[1], G. Luis[1], R. Rogers[1], P. Gigoux[1], H. Solis[1], E. Tollestrup[1], A. Stephens[1], M. Schirmer[1]

[1]*Gemini Obs..*

3:20 PM - 3:30 PM

The FLAMINGOS-2 instrument has been recently refurnished and re-comissioned on the sky in late 2011. In this presentation, I will briefly summarized the work done on the instrument. Moreover, I will show some of the new data obtained with F2 and review its on-sky performance. I will also discuss the upcoming System Verification (SV) call of proposals for the imaging and long slit modes. Finally, I will review the plans for the commissioning and call of proposals for the SV of the MOS mode in early 2012.

414 – Kepler Observations of Exoplanets and Systems

Oral Session – Ballroom G – Thursday, January 12, 2012, 2:00 PM - 3:30 PM

414.01 – **Kepler: Updated Exoplanet Statistics**

William J. Borucki[1], D. G. Koch[1], Kepler Team

[1]*NASA Ames Research Center.*

2:00 PM - 2:10 PM

Analysis of current Kepler observations show the presence of 2000 candidate planets, over 2200 eclipsing binary stars, and variable stars of amazing variety. The sizes of planetary candidates range from that of Mars to over twice the size of Jupiter. Over 100 candidates are found in the habitable zone of the host stars. Candidates smaller than Earth in short period orbits are being detected. Circumbinary planets have been confirmed and many more await confirmation. Hundreds of multi-planet candidates have been found; some with as many as 6 planets. In addition to radial velocity measurements, the observed gravitational interaction between planets in near-resonant orbits is being used to determine planet masses and thus the density of the planets. Searches for planetary moons and rings are underway.

Ongoing follow-up spectroscopic observations and their analyses are providing improvements compared to the values in the Kepler Input Catalog for the stellar temperatures, sizes and metallicities for many of the stars that have become Kepler Objects of Interest. In turn, the new values of stellar properties contribute to better estimates of candidate size and association with stellar characteristics. Improvements to the data analysis pipeline now allow data taken during all quarters to be stitched together to form a contiguous time series that enhance the detection of small planetary candidates in long-period orbits. Intrinsic distributions of the candidates are being derived that allow estimates of the frequency distributions of planet size with semi-major axis and orbital period and to associate the results with stellar characteristics.

414.02 – **Using Spitzer to Estimate the Kepler False Positive Rate and to Validate Kepler Candidates.**

Jean-Michel Desert[1], D. Charbonneau[1], F. Fressin[1], G. Torres[1]

[1]*Harvard-Smithsonian Center for Astrophysics.*

2:10 PM - 2:20 PM

I present the results from an ongoing large campaign with the Spitzer Space Telescope to gather near-infrared photometric measurements of Kepler Objects of Interest (KOI). Our goals are (1) to validate the planetary status of these Kepler candidates, (2) to estimate observationally the false positive rate, and (3) to study the atmospheres of confirmed planets through measurements of their secondary eclipses. Our target list spans of wide range of candidate sizes and periods orbiting various spectral type stars.

The Spitzer observations provide constraints on the possibility of astrophysical false positives resulting from stellar blends, including eclipsing binaries and hierarchical triples. The number of possible blends per star is estimated using stellar population synthesis models and observational probes of the KOI close environments from direct imaging (e.g. Adaptive Optics, Speckle images, Kepler centroids). Combining all the above information with the shape of the transit lightcurves from the Kepler photometry, we compute odd ratios for the 34 candidates we observed in order to determine their false positive probability. Our results suggest that the Kepler false positive rate in this subset of candidates is low. I finally present a new list of Kepler candidates that we were able to validate using this method.

This work is based on observations made with the Spitzer, which is operated by JPL/Caltech, under a contract with NASA. Support was provided by NASA through an award issued by JPL/Caltech. Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

414.03 – **Determining Which Star is the Transit Source in Kepler Data**

Steve Bryson[1], J. M. Jenkins[2], R. L. Gilliland[3], J. F. Rowe[2], G. Torres[4], F. Fressin[4], J. D. Twicken[2], Kepler Science Team

[1]*NASA Ames Research Center,* [2]*SETI Institute/NASA Ames Research Center,* [3]*Space Telescope Science Institute,* [4]*Harvard-Smithsonian Center for Astrophysics.*

2:20 PM - 2:30 PM

The Kepler mission finds exoplanets by detecting planetary transit signals using various centroiding methods that identify false positives due to background eclipsing binaries. One robust, high precision method fits the Kepler PSF to both the out-of-transit target star pixels and the difference between out-of and in-transit pixels. This difference image directly provides the location of the transit signal. The difference between these fits provides a high precision estimate of the offset between the transit signal location and the target star. A large offset implies a BGEB. This method is subject to various biases which complicate its interpretation. These biases change every 3 months because the Kepler spacecraft rolls, placing stars on different pixels. We describe several methods to control these biases through modeling, multi-quarter fitting and robust weighted averaging. These methods achieve uncertainties of less than an arcsec, compared with the prior minimum uncertainty of 2 arcsec (Kepler pixels are 3.98 arcsec on a side). The remaining residual biases are observed to have a nearly Gaussian distribution. These residual biases are combined with modeled observation biases to create observed and expected probability distributions for the transit signal, assuming that the transit is on a particular star. We use these distributions to calculate a relative probability that an observed transit is due to a transit on a specified star. This probability is an important step towards computing an absolute probability that a transit is on the observed target star.

Funding for this mission provided by NASA's Discovery Program Office, SMD.

414.04 – **Exploring Stellar Multiplicity Among Kepler Objects of Interest**

Tim Morton[1], R. Murray-Clay[2], J. A. Johnson[1], G. Marcy[3], A. Howard[3], H. Isaacson[3]

[1]*Caltech,* [2]*Harvard-Smithsonian CfA,* [3]*UC Berkeley.*

2:30 PM - 2:40 PM

The relationship between stellar multiplicity and planet occurrence relates closely to the process of planet formation, but is poorly understood. In particular, close binary systems have typically been selected against by radial velocity planet surveys. Kepler, on the other hand, has in principle no such selection bias, having selected its targets purely on the basis of broadband photometry. The multiplicity of Kepler planet candidate host stars is thus both unknown and of considerable interest. We present results of an ongoing effort to detect or constrain the presence of stellar companions to Kepler Objects of Interest. In addition to questions of planet formation in binary star systems, identifying multiplicity in Kepler host stars is of crucial importance to properly understanding the planet population itself, as the presence of binary companions would cause planet radii to be systematically underestimated.

414.05 – **The Hunt for Exomoons with Kepler**

David M. Kipping[1]

[1]*Harvard-Smithsonian Center for Astrophysics.*

2:40 PM - 2:50 PM

Extrasolar moons may be frequent temperate abodes for life and their detection would not only have astrobiological significance but would also greatly further our understanding of planet/moon formation theories. To date, the bulk of research on this topic has been mostly theoretical, focussing on detection techniques and expected sensitivities as well as exomoon origin and evolution. Here, we introduce a new observational project which aims to change this, enabled by the fact both the theory and available instrumentation have evolved to the required level to make such a search feasible. Our project, "The Hunt for Exomoons with Kepler" (HEK), will be a systematic search for exomoons around planets which are viable hosts, with the explicit goal of determining the frequency of large exomoons in the cosmos. We will overview the observational strategy including the detection tools and target selection routines which have been developed, methods to vet false-positives, and some preliminary results from our first batch of candidates. This research is enabled by the NASA Carl Sagan fellowships for exoplanetary research.

414.06D – **Validating and Characterizing Transiting Exoplanets from Space with**

EPOXI, Kepler, and Warm Spitzer

Sarah Ballard[1]

[1]*Harvard University.*
2:50 PM - 3:10 PM

My thesis work comprises analyses of transiting exoplanets with observations from three space-based instruments. The Extrasolar Planet Observation and Characterization (EPOCh) component of the EPOXI mission repurposed the Deep Impact Spacecraft to gather photometry of six known transiting exoplanet systems. I systematically searched the EPOXI light curves for additional transiting planets, and identified one such candidate in the exoplanet system GJ 436. I gathered Warm Spitzer light curves of GJ 436 during a predicted transit of this putative planet: while I ruled out the presence of the hypothesized planet, I developed a novel reduction technique for Warm Spitzer observations and demonstrated the sensitivity of that instrument to sub-Earth-sized transiting planets. I next applied these techniques to a sample of super-Earth-sized planetary candidates identified by the Kepler mission. In the absence of radial velocity confirmation (challenging for such low-mass planets), it is nonetheless possible to make a statistical argument for the planetary nature of the candidate, if the combined likelihood of all false positive scenarios is sufficiently smaller than the planet scenario. An authentic planet will exhibit an achromatic transit depth, as measured in the optical with Kepler and near-infrared with Warm Spitzer. The eclipse from a stellar blend, in contrast, would likely vary with wavelength. I presented the discovery of the Kepler-19 system, applying Warm Spitzer observations toward validation of the transiting 2.2 R_{Earth} planet, Kepler-19b. I identified systematic variations in the transit times of Kepler-19b, which led to the first robust detection of a non-transiting planet using the transit timing variation method: Kepler-19c.

Support for EPOXI was provided by NASA's Discovery Program via Agreement NNX08AB64A. This work is based on observations made with the Spitzer Space Telescope. Support for Spitzer observations is provided by NASA through an award issued by JPL/Caltech.

414.07 – **The *Kepler* Search for Circumbinary Planets**

William F. Welsh[1], Kepler Team

[1]*San Diego State Univ..*
3:10 PM - 3:20 PM

We present the latest results from the *Kepler* search for planets in binary star systems, including transiting and non-transiting cases. In many cases, eclipse timing variations (ETVs) indicate the presence of a third body in the system. If the O-C diagram exhibits a small amplitude and short-period signal, that third body may be planetary. Kepler-16, along with several other candidate systems, will be discussed.

Kepler was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate. The authors also acknowledge support from the *Kepler* Participating Scientists Program via NASA grant NNX08AR14G.

414.08 – **GJ 581 Update: An Independent Re-analysis Of The HARPS Data Set**

Steven S. Vogt[1], R. Butler[2], E. R. Rivera[1], N. Haghighipour[3]

[1]*UC, Santa Cruz,* [2]*Carnegie DTM,* [3]*IFA Hawaii.*
3:20 PM - 3:30 PM

We present an independent re-analysis of the HARPS precision radial velocity data set for Gliese 581 that was recently published by Forveille et al. (2011). We perform both non-interacting as well as interacting 4-planet fits to the data. Our analysis reaches substantially different conclusions than those presented by Forveille et al.

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415 – Science Highlights from NASA's Astrophysics Data Analysis Program II

Special Session – Room 16B – Thursday, January 12, 2012, 2:00 PM - 3:30 PM

Over the years, NASA has invested heavily in the development and execution of an extensive array of space astrophysics missions. 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 from investigators supported under the ADAP Program.

415.01 – **A Multiwavelength Investigation of a Suspected IMBH Tidal Disruption Event Within an Extragalactic Globular Cluster**

Jimmy Irwin[1], K. Chiboucas[2], D. Clausen[3], S. Sigurdsson[3], M. Eracleous[3], R. Dupke[4]

[1]*Univ. Of Alabama,* [2]*Gemini Observatory,* [3]*Penn State University,* [4]*Observatorio Nacional, Brazil, Brazil.*
2:00 PM - 2:10 PM

In previous studies, we have presented evidence that the ultraluminous X-ray source CXOJ033831.8-352604 within a luminous globular cluster of the Fornax elliptical galaxy NGC1399 represented the aftermath of a tidal disruption event by an intermediate-mass black hole within the globular cluster. This intriguing source exhibited X-ray variability, and more importantly, strong [O III] and [N II] emission that we postulate emanates from the X-ray photoionization of the debris from a disrupted white dwarf or horizontal branch star that was town apart by the IMBH. Here, we present Gemini GMOS spectra of the source to search for [O II] emission from the line-emitting debris. We also determine an X-ray spectrum for the source from a long archival XMM-Newton observation. Finally, we compare our line ratios to a suite of tailored simulations of the tidal disruption of a horizontal branch star by a ~100 solar mass black hole and find good agreement, supporting our IMBH-tidal disruption scenario.

415.02 – **Galaxy Formation in Action: A Multi-Wavelength Study of Ly-alpha Nebulae in the Distant Universe**

Ann I. Zabludoff[1]

[1]*University of Arizona.*
2:10 PM - 2:30 PM

Lyman-alpha blobs are mysterious objects in the distant Universe extending over 50-100 kpc. Because these gigantic gas clouds have been detected only in optically thick and highly resonant Lyman-alpha emission, their power source remains a puzzle. Due to the rarity of blobs, the form of their evolution to the present day is also unknown. We are conducting multi-wavelength, deep, and large area surveys to identify tens of blobs at redshifts ~2-5. These surveys have now produced the first constraints on blob clustering, showing that blobs occupy massive halos likely to evolve into rich clusters today. Blobs are not only tracers of the most overdense environments at early times, but also may mark the sites of brightest cluster galaxy formation. By targeting the optically-thin lines such as Halpha, we have obtained the first measurements of gas kinematics in blobs, excluding strong outflows as the source of Lyman-alpha emission.

415.03 – **Ultraviolet Properties of Nearby Galaxies from Swift UV/Optical Telescope Imaging**

Erik A. Hoversten[1], J. Berrier[1], C. Conroy[2], C. Gronwall[1]

[1]*Pennsylvania State University,* [2]*Harvard-Smithsonian Center for Astrophysics.*
2:30 PM - 2:40 PM

We present UVOT imaging of a sample of 25 nearby star forming galaxies. Most of these galaxies are included in the Spitzer Infrared Nearby Galaxies Survey (SINGS) and have been observed by Spitzer in the Infrared as well as at optical wavelengths. We use the UVOT near ultraviolet imaging in conjunction with ground based optical and Spitzer infrared data to investigate the recent star formation in these galaxies as a function of galaxy properties. Additionally, given the spectral resolution UVOT provides in the near UV we are able to constrain the stength of the 2175 Å dust bump in these galaxies. We investigate variations of the bump strength as a function of the physical properties of the galaxies, as well as spatial variations within the galaxies. In particular we correlate the 2175 Å bump strength with polycyclic aromatic hydrocarbon (PAH) features in the infrared to test the hypothesis that PAHs give rise to the bump. This project was funded in part by the NASA Astrophysics Data Analysis Program.

415.04 – **Quasar SEDs From The SAFIRES Archival Survey**

Daniel Hanish[1], H. Teplitz[1], P. Capak[2], SAFIRES team

[1]*Infrared Processing and Analysis Center,* [2]*California Institute of Technology.*
2:40 PM - 2:50 PM

The best current infrared quasar spectral energy distribution (SED) templates (e.g. Polletta et al. 2007) rely on statistically limited samples, in the tens of objects. In contrast, the Spitzer Source List and the Spitzer Archival Far-IR Extragalactic Survey (SAFIRES) provide data in seven bands, ranging in wavelength from 3 to 160 microns, for thousands of Sloan Digital Sky Survey (SDSS) spectroscopic quasars.

Using these data and the Bayesian eigenspectra template reconstruction approach described in Budavári et al. (2001), we generate a more representative set of mid-infrared quasar templates than were previously feasible. Here we present our results, based on all quasars identified in the Spitzer Source List.

415.05 – **Measuring the 'Dark Flow' of Galaxy Clusters with X-ray and CMB**

Data: Methods, Results and Implications

Alexander Kashlinsky[1]

[1]*NASA's GSFC.*

2:50 PM - 3:10 PM

I will report on the current status of the investigation into peculiar motion of galaxy clusters which was supported and made possible through two NASA ADP awards. In standard cosmological paradigm, large-scale peculiar velocities arise from gravitational instability due to mass inhomogeneities seeded during inflationary expansion. On sufficiently large scales, > 100 Mpc, this leads to a robust prediction of the amplitude and coherence length of these velocities independently of cosmological parameters or evolution of the Universe. For clusters of galaxies, their peculiar velocities can be measured from the kinematic component of the Sunyaev-Zeldovich (SZ) effect produced by Compton scattering of cosmic microwave background (CMB) photons off the hot intracluster gas. I will discuss results from new measurements of the large scale peculiar flows using a large X-ray cluster catalog and all-sky CMB maps from the WMAP satellite. The results cast doubt that the gravitational instability from the observed mass distribution is the sole - or even dominant - cause of the detected motions. Instead it appears that the flow extends across the observable Universe and may be indicative of the primeval preinflationary structure of space-time and its landscape.

415.06 – **The Swift Serendipitous Cluster Survey**

Xinyu Dai[1], J. N. Bregman[2], C. S. Kochanek[3]

[1]*Univ. of Oklahoma,* [2]*Univ. of Michigan,* [3]*Ohio State University.*

3:10 PM - 3:20 PM

The Swift XRT observations of GRBs form a serendipitous survey for galaxy clusters with the potential to generate one of the largest X-ray selected cluster catalogs. Based on six years of Swift archival data, we extracted 800 cluster candidates using X-ray data alone. We also present our optical follow-up observations for a portion of the Swift fields using the 2.4m MDM telescope aiming at increasing the number of X-ray selected z>0.5 clusters.

415.07 – **Constraining The Formation And Evolution Of Young X-ray Binaries In The Nearest Star-Forming Galaxies**

Vallia Antoniou[1], A. Zezas[2], T. Linden[3], V. Kalogera[4]

[1]*Iowa State University,* [2]*University of Crete, Greece,* [3]*University of California, Santa Cruz,* [4]*Northwestern University.*

3:20 PM - 3:30 PM

The Small and Large Magellanic Cloud offer a unique environment to study the populations of young (<100 Myr) X-ray binaries (XRBs). The detailed multi-wavelength studies of these two nearby star-forming galaxies have furthered our understanding of the mechanisms involved in the XRB formation and evolution and provide constraints on current population synthesis models. Here, we present our more recent work on the parameters affecting these systems such as the age, the metallicity and the star-formation rate of their parent stellar populations probed by the use of Infrared (Spitzer), optical (photometric and spectroscopic), and X-ray (Chandra and XMM-Newton) data. Such comprehensive studies provide unique insights on the observational characteristics of young XRBs in other distant star-forming galaxies for which it is not possible to reach these faint luminosity levels. This work is supported by the National Aeronautics and Space Administration under Grant No. NNX10AH47G issued through the Astrophysics Data Analysis Program.

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416 – Starburst Galaxies

Oral Session – Ballroom F – Thursday, January 12, 2012, 2:00 PM - 3:30 PM

416.01D – **Shocked Outflows and Gas Disks in Local Merging Galaxies**

Kurt Soto[1], C. L. Martin[1], M. K. M. Prescott[1], L. Armus[2]

[1]*UC Santa Barbara,* [2]*Spitzer Science Center, California Institute of Technology.*

2:00 PM - 2:20 PM

We have mapped the kinematic and physical properties of gas emitting optical emission lines across 39 gas-rich mergers, which were previously shown to host tidally-induced gas inflows, with deep ESI spectroscopy. In our unique analysis of these longslit spectra, we fitted multiple kinematic components to forbidden lines and recombination lines simultaneously, enabling an examination of the excitation mechanism in different kinematic components. We identify many rotating gas disks in systems whose stellar component is no longer a disk due to the merger. Many of these disks present gas excited by hot stars, but some of the disks present shock-like ratios of diagnostic emission lines, an observation we attribute to the collision of the two galaxies. In another subset of galaxies, we find very broad (sigma > 150 km/s) emission components that also present shock-like emission-line ratios. The large spatial extent of this emission favors shocks over the narrow-line region of a hidden AGN as the excitation mechanism. The high star formation rate, high dust content, and blueshift of the broad emission further suggest an origin in a galactic outflow. If this interpretation is correct, then our study of these nearby galaxies provides important insight for interpreting the broad emission lines associated with giant star-forming clumps in z~2 galaxies. It also shows that galactic outflows can be recognized via resolved emission lines, in addition to absorption lines, even in integrated spectra; and this technique could prove very powerful for studying galactic outflows in infrared spectra of high-redshift galaxies in the future.

This work was supported by the National Science Foundation under contract 0808161.

416.02 – **A Strongly Lensed Planck Source at z = 3.26**

Hai Fu[1], E. Jullo[2], A. Cooray[1], H-ATLAS Team

[1]*University of California, Irvine,* [2]*Astronomy Observatory of Marseilles Provence, France.*

2:20 PM - 2:30 PM

We report the discovery of a strongly lensed Planck-detected source at z = 3.26. The lensing nature of G12v2.30 was confirmed during our Keck Adaptive Optics imaging program of bright Herschel 500um sources from H-ATLAS. The 0.1"-resolution K-band image shows multiple lensed images across a 4" area, while the 2"-resolution Submillimeter Array image shows two 880um sources separated by 3". The positions of the submillimeter sources do not match those of the K-band sources, indicating differential magnifications due to a spatial offset between the rest-frame g-band stellar emission and the dust emission on the source plane. We construct a lens model by fitting the positions of the conjugate multiple images in the K-band and by assuming singular isothermal ellipsoid dark matter halos associated with the group of lensing galaxies at z ~ 1.0. We then constrain the location of the 880um emission on the source plane with the best-fit lens model and the observed 880um image. The reconstructed source plane image shows two merging galaxies with the optical nuclei separated by 0.75 kpc (0.1") and a submillimeter source 2.2 kpc (0.3") north of the optical galaxies. The optical emission is magnified by a factor of ~13, while the submilimeter emission is magnified by a factor of only ~5. Our SED fitting indicates a dust temperature of ~43 K and an obscured SFR of ~900 M_sun/yr after correcting for the amplification. G12v2.30 provides a prelude to hundreds of lensed submillimeter galaxies from H-ATLAS that will be studied in depth with existing facilities.

416.03 – **HST/COS Observations Of Lyman-α Emission From <z>=0.03 Star Forming Galaxies**

Aida Wofford[1], C. Leitherer[1], J. Salzer[2], COS Science Team

[1]*STScI,* [2]*Indiana University.*

2:30 PM - 2:40 PM

Although HI Lyman-alpha (Lyα, 1216 Å) is expected to be the strongest recombination line in HII nebulae, it is resonantly scattered by neutral hydrogen and is easily destroyed by dust. And yet, some star-forming galaxies show Lyα in emission. As evidenced by high dispersion HST/GHRS+STIS FUV spectroscopy of a handful of local (z<0.03) galaxies, the velocity shift between the neutral gas and the ionized gas plays a key role in driving the observed Lyα escape. We present HST/COS/G130M 1150-1450 Å (observed-frame) spectroscopy of 20 new targets located at a mean redshift of <z>=0.03. The targets were selected from the KISSR survey on the basis of their GALEX FUV continuum luminosity. The observations cover the central ~1-2 kpc of each galaxy, a wide range in metallicity ([O/H]=-0.83 to 0.38), and at least two orders of magnitude in FUV continuum luminosity. Seven objects show Lyα emission in the form of a P-Cygni or double-peaked profile. For 6/7 of the latter objects we are able to show that the emission is accompanied of O I gas outflows with speeds of up to ~200 km/s. Two objects have Lyα luminosities comparable to the GALEX Lyα luminosities of targets at <z>=0.3, but we find no Lyα emitters with EW(Lyα)>20 Å, such as those discovered with GALEX at z=0.2-0.35. We compare the observed Lyα/Hα line intensity ratios with predictions from dust-free cases A and B recombination under normal HII region conditions. We find evidence of O I gas inflow in the most metal-poor objects. This work is supported by NASA grant N1317.

416.04 – **Clustering, Halo Mass, and Evolution of Submillimeter Galaxies**

Ryan C. Hickox[1], LESS Collaboration

[1]*Dartmouth College.*

2:40 PM - 2:50 PM

We present a new and accurate measurement of the spatial clustering of submillimeter galaxies (SMGs), the most powerful starbursts in the Universe. We employ a novel technique using data from the LABOCA ECDFS Submillimeter Survey (LESS) to obtain the linear bias and dark matter halo mass for 870-micron selected SMGs. We find that SMGs at z~2 reside in halos of characteristic mass log(M_halo [M_sun/h]) = 12.8 (+0.3,-0.5), providing support for evolutionary links between SMGs and quasars, and indicating that SMGs evolve into massive early-type galaxies residing in moderate- to high-mass groups. Given the observed halo mass, we demonstrate that the redshift

distribution of SMGs can be described remarkably well by the combination of two effects: the cosmological growth of structure and the evolution of the molecular gas fraction in galaxies. We conclude that the powerful starbursts in SMGs likely represent a short-lived but universal phase in massive galaxy evolution, associated with the transition between cold gas-rich, star-forming galaxies and passively evolving systems.

416.05 – **Luminous Blue Compact Galaxies: Probes of Galaxy Assembly**

Cassidy L. Newton[1], M. Fanelli[2], P. Marcum[2]

[1]*Texas Christian Univesity,* [2]*NASA AMES.*

2:50 PM - 3:00 PM

The life cycles of galaxies over cosmic time is yet to be fully understood. To build the population observed now, galaxies experienced significantly larger star formation rates (SFR) at earlier epochs; the peak of global star formation is posited to have occurred at z~2. In this project we interpret the evolutionary state of a sample of Luminous Blue Compact Galaxies (LBCGs), galaxies in the local ($z < 0.05$) universe exhibiting blue colors, [$(B-V) \leq 0.5$], absolute luminosities comparable to bright galaxies, ($MB < -19$), and high SFRs [10-50 M(sun) per year]. Due to the scale of this star formation, LBCGs appear to be ideal local analogs to the early evolutionary phases of most galaxies. Their location in the near-field permits detailed investigation over a broad range of the electromagnetic spectrum with high spatial resolution, permitting the processes of galaxy assembly to be examined in great detail. While LBCGs appear to be rapidly evolving systems, the mechanisms driving this evolution, the progenitor population and final morphological state are little understood.

We combine optical imagery (UBVR,Hα) obtained at McDonald Observatory with UV photometry from GALEX, thermal-infrared photometry from IRAS, and radio data to investigate the structure and star formation history for ~50 LBCGs. Multi-band surface photometry is used to quantify the formation rate and spatial distribution of young stars, and assesses the degree to which these systems are or have interacted with nearby galaxies. While a substantial number of systems are mildly or strongly interacting, the sample is not dominated by interactions, indicating that internal processes can trigger strong star formation episodes. Comparison of SFRs estimated using far-IR and ultraviolet data generally finds infrared-derived rates significantly higher, yet most LBCGs are strongly detected with GALEX, suggesting long-lived starbursts. We highlight possible evolutionary connections between LBCGs, ultraluminous infrared galaxies, and post-starburst systems.

416.06 – **Identification of a Fundamental Transition in a Turbulently-Supported Interstellar Medium**

Evan Scannapieco[1], W. Gray[1], L. Pan[1]

[1]*Arizona State University.*

3:00 PM - 3:10 PM

The interstellar medium in star-forming galaxies is a multiphase gas in which turbulent support is at least as important as thermal pressure. Sustaining this configuration requires continuous radiative cooling, such that the cooling rate matches the decay rate of turbulent energy into the medium. Here we carry out a set of numerical simulations of a stratified, turbulently stirred, radiatively cooled medium, which uncover a fundamental transition at a critical, one-dimensional turbulent velocity of ≈ 35 km/s. At turbulent velocities below ≈ 35 km/s, corresponding to temperatures below 300,000K the medium is stable, as the time for gas to cool is roughly constant as a function of temperature. On the other hand, at turbulent velocities above the critical value, the gas is shocked into an unstable regime in which the cooling time increases strongly with temperature, meaning that a substantial fraction of the interstellar medium is unable to cool on a turbulent decay time. This naturally leads to runaway heating and gas outflows in any medium with a one-dimensional turbulent velocity above ≈ 35 km/s, a result that has implications for galaxy evolution at all redshifts.

416.07 – **Mcmc Sed Fitting Of Candels Galaxies: A Realistic Error Budget**

Viviana Acquaviva[1], E. Gawiser[1], CANDELS team

[1]*Rutgers, The State University of New Jersey.*

3:10 PM - 3:20 PM

Spectral Energy Distribution (SED) fitting is a powerful tool to gain insights on galaxy formation and evolution. The Markov Chain Monte Carlo technique allows one to explore large parameter space efficiently, as well as to reveal degeneracies and compute uncertainties accurately. However, systematic errors associated to the assumptions made in modeling the stellar populations, which are often a major source of uncertainty, need to be properly taken into account. We perform SED fitting using the publicly available code GalMC (Acquaviva et al 2011) on several thousand galaxies with spectroscopic redshifts imaged by the CANDELS survey in GOODS-S. We evaluate and compare the relative impact of statistical and systematic uncertainties on the parameters of SED fitting, allowing in particular different choices for the initial mass function, stellar population synthesis model, and dust absorption law.

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417 – Evolution of Galaxies VIII

Oral Session – Room 19A – Thursday, January 12, 2012, 2:00 PM - 3:30 PM

417.01 – **The Demographics of Bulges in the Local Universe**

David B. Fisher[1], N. Drory[2]

[1]*University of Maryland,* [2]*Universidad Nacional Autonoma de Mexico, Mexico.*

2:00 PM - 2:10 PM

We report on our recent study to provide an inventory of galaxy bulge types (elliptical galaxy, classical bulge, pseudobulge, and bulgeless galaxy) in a volume-limited sample within the local 11 Mpc volume using Spitzer 3.6 micron and HST data. We find that whether counting by number, star formation rate, or stellar mass, the dominant galaxy type in the local universe has pure disk characteristics (either hosting a pseudobulge or being bulgeless). Galaxies that contain either a pseudobulge or no bulge combine to account for over 80% of the number of galaxies above a stellar mass of 10^9 M_{sun}. Classical bulges and elliptical galaxies account for ~1/4, and disks for ~3/4 of the stellar mass in the local 11 Mpc. About 2/3 of all star formation in the local volume takes place in galaxies with pseudobulges. It has been suggested that pseudobulges are formed via internal disk instabilities. If this is true, and pseudobulges are not a product of mergers, then the frequency of pseudobulges in the local universe poses a challenge for galaxy evolution models which assume that bulge-to-total ratio is a function only of the merging process.

417.02D – **Astrophysically Motivated Bulge-Disk Decompositions in SDSS**

Claire Lackner[1], J. Gunn[1]

[1]*Princeton University.*

2:10 PM - 2:30 PM

The division of galaxies into disk and spheroid components is very old and reasonably successful. I will discuss a new set of two-dimensional bulge-disk(B+D) decompositions for 70,000 nearby Sloan Digital Sky Survey (SDSS) galaxies, the largest such set to date. Each galaxy is fit with five different 2-dimensional models and the best fitting model is selected based on chi-squared values and astrophysical constraints (color, bulge-to-total ratio, shape, etc.). Fifty percent of the galaxies cannot be fit with a B+D model, but this represents only 20% of the stellar mass in our sample. Bulge color and shape can be used to separate elliptical-like classical bulges from disk-like pseudo-bulges and this method agrees reasonably well with other methods used to distinguish classical bulges from pseudo-bulges. This large data set can be used to study the properties of different morphological types over a large range of galaxy properties and environments.

417.04 – **Thick Disks seen in the Spitzer Survey of Stellar Structure in Galaxies**

Johan H. Knapen[1], S. Comeron[2], B. Elmegreen[3], K. Sheth[4], S4G collaboration

[1]*Instituto de Astrofisica de Canarias, Spain,* [2]*KASI, Korea, Republic of,* [3]*IBM,* [4]*NRAO.*

2:50 PM - 3:00 PM

Most, if not all, disk galaxies have a thin (classical) disk and a thick disk. In most models thick disks are thought to be a necessary consequence of the disk formation and/or evolution of the galaxy. We present the results of a study of the thick disk properties in edge-on galaxies from mid-IR imaging obtained in the Spitzer Survey of Stellar Structure of Galaxies (S4G, PI Kartik Sheth). We fitted one-dimensional luminosity profiles with physically motivated functions - the solutions of two stellar and one gaseous isothermal coupled disks in equilibrium - which are likely to yield more accurate results than the other functions used in previous studies. We found that thick disks are on average more massive than previously reported, mostly due to the selected fitting function. Typically, the thin and the thick disk have similar masses. Our results tend to favor an in situ origin for most of the stars in the thick disk. In addition the thick disk may contain a significant amount of stars coming from satellites accreted after the initial build-up of the galaxy and an extra fraction of stars coming from the secular heating of the thin disk by its own

overdensities. Assigning thick disk light to the thin disk component may lead to an underestimate of the overall stellar mass in galaxies, because of different mass to light ratios in the two disk components. On the basis of our new results, we estimate that disk stellar masses are between 10% and 50% higher than previously thought and we suggest that thick disks are a reservoir of "local missing baryons".

417.05 – **Ultra-Violet Analysis of the S4G Sample**

Raquel Chicharro-Fuertes[1], A. Gil de Paz[1], K. Sheth[2], J. Munoz-Mateos[2], Spitzer Survey of Stellar Structure in Galaxies (S4G) team

[1]*Universidad Complutense De Madrid, Spain,* [2]*National Radio Astronomy Observatory.*

3:00 PM - 3:10 PM

We have carried out two different studies by combining ultra-violet (UV) data from NASA's GALEX satellite and infrared data from the Spitzer Survey of Stellar Structure in Galaxies (S4G).

Quantifying the evolution of the bar fraction across the cosmic time can shed light on the process of disk assembly. However, studies of the bar fraction at high redshift are hampered by the fact that optical observations probe the UV rest frame regime, where bars tend to be much less prominent as a consequence of the Balmer Break. In order to quantify this bias, we have studied the bar frequency in the UV for the S4G sample, using GALEX data. Our results yield a UV bar fraction between 0.09-0.19 for the S4G sample, where the larger figure is an upper limit that includes candidate bars. This is quite low as compared to 0.65, which is the typical value found in optical and near-infrared studies (NIR). As a second part of this work, we will discuss the scenarios of disks formation. The addition of UV data provided by NASA's GALEX satellite, allows us to derive (1) the spatially-resolved star formation rate and (2) the attenuation of the stellar light by interstellar dust.

Comparing the radial distribution of young stars to the total of stellar mass is a crucial test to prove the scenarios for disk evolution, especially the inside-out scenario and possible deviations from it due to accreting satellites, stellar migration or interaction with the environment. In this work, we have compiled the images at the near ultra-violet (NUV) and far ultra-violet (FUV) for the whole sample and have obtained surface brightness and color profiles, as well as their UV fluxes in order to compare them to the parameters that have been derived from the IR bands of the Warm Spitzer mission.

417.06 – **Measuring the Fraction of Bars and Offset Bars Using the Spitzer Survey of Stellar Structure in Galaxies**

Alexa Ross[1]

[1]*Reed College.*

3:10 PM - 3:20 PM

Using the Spitzer Survey of Stellar Structure in Galaxies at 3.6 and 4.5μm, I have measured a preliminary bar fraction and offset bar fraction in the local universe by visually identifying bar structure within a sample of 2,140 local galaxies. A sample this large has not been used since 1963, when Gerard de Vaucouleurs found the bar fraction to be roughly fbar ~ 0.6 in the Third Reference Catalog of Bright Galaxies. Since then, there has been much debate over the true value of the bar fraction. The purpose of finding a bar fraction using S4G is to provide a final say in this debate. I have found that the bar fraction in the local universe is fbar = 0.69 when including both definite bars (SB) and candidate bars (SAB). I have also measured a preliminary value for the fraction of offset bars using the same sample. Offset bars are a very rare phenomenon. Of the sample used, 91 galaxies are found to be definite offset bars while an additional 39 are found to be candidate offset bars. When including both definite offset bars and candidate offset bars, the offset bar fraction in the local universe becomes fob = 0.12. I also measure the fraction of offset bars as a function of Hubble type and stellar mass. We find that 54% of offset bars are found in disks having a stellar mass of $M \leq 10^8$ $M_\odot$. Late-type disks possess significantly more offset bars than early-type with 60% of offset bars being found in disks having a Hubble type $t \geq 6$.

417.07 – **Relative Fraction of E, S0, and Strong Barred Galaxies in Groups and Clusters in the Nearby Universe, 0 Less than Z Less than 0.066, as a Function of Redshift**

Jose A. Garcia-Barreto[1]

[1]*Univ. Nac. Autonoma de Mexico (UNAM), Mexico.*

3:20 PM - 3:30 PM

A Statistical analysis of 903 groups and 56 clusters (with a total of 10,316 galaxies) has been done in order to estimate the relative fraction of E, S0, and strong barred (SB) galaxies in the redshift interval $0 < z < 0.066$. Our sample has been taken from the published catalogs: a) Nearby Galaxy (Huchra & Geller 1982), CfA (Geller & Huchra 1983), Tully Catalog (Tully 1987) and Abell Clusters (Dressler 1980). Our results, in terms of median values expressed in percentages, for groups and clusters (each with more than 10 galaxies) are:

a) SB/(S+SB) decreases from 43 {+16}{-14} % at z=0, to 28 {+10}{-8} % at z=0.031, to 23 {+8}{-11} % at z=0.066,

b) S0/N increases from 0 {+15}{-0} % at z=0, to 33 {+5}{-7} % at z=0.066,

c) E/N increases from 0 {+17}{-0} % at $0 < z < 0.0099$ to 10 {+11}{-2} % at z=0.0129 and stays relatively constant at 11 {+8}{-3} % at z=0.066, and finally,

d) the ratio S0/E increases from 0 at z=0, to S0/E=0.40 {+0.53}{-0.10} at z=0.0129, to S0/E=0.67 {+1.2}{-0.33} at z=0.031, to S0/E=2.5 {+0.83}{-0.83} at z=0.031, and finally to S0/E=3.0 {+2.2}{-1.0} at z=0.066.

Our result for the median value of the relative fraction of SB galaxies in groups and clusters (each with more than 10 galaxies) does not agree with the optical r-band fraction of 48 % reported by Barazza et al. (2008) in the interval $0.01 < z < 0.03$.

JAG-B acknowledges financial support from DGAPA (UNAM), Mexico grant IN108011-2.

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418 – Planetary Nebulae, Supernova Remnants and Supernovae

Oral Session – Room 12A – Thursday, January 12, 2012, 2:00 PM - 3:30 PM

418.01 – **Do Most Planetary Nebulae Derive from Binary Interactions? The Binary Fraction of Central Stars of Planetary Nebula**

Orsola De Marco[1], D. Douchin[1], J. C. Passy[2], G. H. Jacoby[3], D. J. Frew[1], T. Hillwig[4]

[1]*Macquarie University, Australia,* [2]*American Museum of Natural History,* [3]*Giant Magellan Telescope,* [4]*Valparaiso University, Australia.*

2:00 PM - 2:10 PM

During the past 20 years, the idea that non-spherical planetary nebulae, comprising 80% of the total population, might need a binary or planetary interaction to be shaped, was discussed by various authors. It is now generally agreed that the varied morphologies of planetary nebulae cannot currently be explained by rotation and magnetic fields in single giant stars. Observationally, more binary central stars of planetary nebula have been discovered, opening new possibilities to understand the connections between binarity and morphology. So far, ~45 binary central stars of planetary nebulae have been detected, most being close systems detected via flux variability. In order to determine the actual PN binary fraction, one needs a method that can detect wider binaries. We present here early results from a survey of high precision I-band and near infrared photometry of planetary nebula central stars aimed at detecting binaries with any separation. Eventually our survey will sample most of the 2-kpc volume limited sample of Frew (2008). At that time we expect that the binary fraction will reveal whether PN derive primarily from binaries or whether the current scenario, whereby single stars somehow, can generate non spherical planetary nebulae, is more in line with observation.

418.02 – **Using Kepler to Measure the Binary Fraction of Planetary Nebula Central Stars**

George Jacoby[1], O. De Marco[2], S. Howell[3], M. Kronberger[4]

[1]*GMT / Carnegie Obs,* [2]*Macquarie University, Australia,* [3]*NASA ARC,* [4]*CERN, Switzerland.*

2:10 PM - 2:20 PM

The Kepler Observatory offers unprecedented photometric precision (<1 mmag) and cadence for monitoring the central stars of planetary nebulae (CSPN), allowing the detection of tiny light curve variations, a possible signature of binarity. With these precisions free from the observational gaps dictated by weather and lunar cycles, we are able to detect CSPN companions at much larger separations, with much smaller masses, and much longer periods than ever before.

We have been awarded targeted observing time to obtain light-curves of the four known CSPN, plus one possible PN, plus one newly discovered PN in the Kepler field at cadences of both 30 min and one min for each of these CSPN. Five of the six objects have preliminary data. They are all periodic variables, although for two of them with the smallest amplitudes, the uncertainties are large. Preliminary analysis indicates that the periods span a range of 0.2 to 3.0 days, while the amplitudes lie between 0.002 and 0.050 mags. Only one of these objects would have been identified as variable in a typical ground-based program.

418.03 – **The Origin of Kepler's Supernova Remnant**

Daniel Patnaude[1], C. Badenes[2], S. Park[3]

[1]*Harvard-Smithsonian, CfA,* [2]*University of Pittsburgh,* [3]*University of Texas at Arlington.*

2:20 PM - 2:30 PM

It is now well established that Kepler's supernova remnant (SNR) is the result of a Type Ia explosion. With an age of 407 yr, Kepler is estimated to be 3.5 to 7.5 kpc distant, with an angular diameter of ~ 5 arcminutes. Unlike other Galactic Type Ia SNRs (e.g. Tycho's SNR and SN 1006), Kepler shows strong evidence for a circumstellar interaction. A bowshock structure in the north of the SNR is thought to originate from the movement of the mass-losing progenitor through the interstellar medium prior to the

supernova. We present results of a modeling campaign aimed at constraining the mass-loss history of the progenitor and the amount of 56Ni synthesized in the explosion through hydrodynamic and NEI calculations of the SNR evolution. We simulate the interaction of realistic SN Ia ejecta models with circumstellar density profiles sculpted by mass loss from several SN Ia progenitor scenarios and compare the results to the bulk properties of the X-ray emission and SNR dynamics.

418.04 – **Fermi Observations of Flares from the Crab Nebula**

Roger D. Blandford[1], R. Buehler[1], S. Funk[1]

[1]*Stanford University.*

2:30 PM - 2:40 PM

Recent gamma ray observations of the Crab Nebula by the Fermi and AGILE telescopes have found strong flares that are not conspicuous at other frequencies or in the pulsar timing record. The timescales can be as short as hours and the peak powers a few percent of the average nebular power. These observations may be striking examples of a more general phenomenon involving surprisingly rapid variability of extended high energy sources as observed by Chandra, Swift and Hubble. Interpretations of these flares involving relativistic shocks and line currents will be described along with plans for observing future Crab flares.

418.05 – **Probing the Unique Morphology and Plasma Conditions of W49B with Chandra**

Laura A. Lopez[1], E. Ramirez-Ruiz[2], E. Figueroa-Feliciano[1]

[1]*MIT,* [2]*UC Santa Cruz.*

2:40 PM - 2:50 PM

We present new results from a recent 220-ks Chandra observation of the galactic supernova remnant (SNR) W49B. W49B has several unique morphological and spectral features which are not found in other SNRs: it is the only SNR with large-scale segregation of its nucleosynthetic products, its X-ray spectrum is suggestive of rapid cooling uncommon in SNRs, and it is the only core-collapse SNR to date with detected lines from the heavy elements chromium and manganese. We have performed detailed X-ray morphological and spatially-resolved spectroscopic analyses of this deep observation, and we will highlight the preliminary findings related to the physical conditions and explosive origin of W49B.

418.07 – **Detonation Waves in Supernova Remnants**

Yang Gao[1], C. K. Law[2]

[1]*Tsinghua University, Beijing, China,* [2]*Princeton University.*

3:00 PM - 3:10 PM

Contrary to the deceleration in the propagation of spherically expanding blast waves, the expansion of the Crab nebula shock front is accelerative according to observations in the last decades. We shall see that this acceleration is because of the detonation wave initiated by the strong shock between the nebula and the surrounding interstellar medium. This detonation wave, with an energy-generating reactive downstream, provides the needed power to maintain the propagation of the outer envelope of the nebula. Furthermore, relaxation of the curvature effect, which causes the reduction of the propagation velocity form the asymptotic planar state of Chapman-Jouguet velocities, explains the observed accelerative expansion of the shock front. The existences of detonation waves in other supernova remnants as well as the potential richness of reactive fluid fronts in various astronomical systems are also discussed. This work is supported by the startup fund for the Center for Combustion Energy at Tsinghua University.

418.08D – **The Local Type Ia Supernova Progenitors: One Double-Degenerate, No Symbiotics**

Ashley Pagnotta[1], B. E. Schaefer[1]

[1]*Louisiana State University.*

3:10 PM - 3:30 PM

Although the basic mechanism responsible for Type Ia supernovae appears to be well understood (thermonuclear explosion of a carbon-oxygen white dwarf that has reached the Chandrasekhar mass limit), the identity of the progenitor system(s) remains a mystery. With implications from stellar evolution to frontline cosmology, it is critical to attack this problem from every possible angle. We present results from our study of three known historical Ia supernovae in the Large Magellanic Cloud (LMC) which allow us to eliminate possible progenitor candidates for at least the local population. We used archival Hubble Space Telescope images of SNR 0509-67.5, SNR 0509-68.7, and SNR 0519-69.0 to determine the site of each explosion and then search the surrounding area for potential ex-companion stars that were left behind. The search was carried out within an error ellipse that accounts for measurement error on the geometric center of the remnant, the orbital velocity of the pre-supernova binary system, and kicks from the actual explosion. For SNR 0509-67.5, the error ellipse is empty to the HST 5σ limiting magnitude of V=26.9. Using an LMC distance modulus of 18.5, this implies that any single degenerate ex-companion must be fainter than M_V=+8.4 (corresponding approximately to a K9 main sequence star), which eliminates all currently-published single-degenerate models and leads us to conclude that this system had a double-degenerate (double white dwarf) progenitor. For SNR 0509-68.7 and SNR 0519-69.0, we can eliminate the possibility of red giant and subgiant ex-companions. It has been shown that the two confident galactic Ia supernovae (Tycho's SN 1572 and SN 1006) also do not have red giant ex-companion stars. Combined with our three systems, this eliminates the symbiotic progenitor channel for all of the nearby Ia supernovae.

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419 – Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS) II

Special Session – Ballroom E – Thursday, January 12, 2012, 2:00 PM - 3:30 PM

The Cosmic Assembly Near-IR Deep Extragalactic Legacy Survey (CANDELS)is the largest survey yet conducted with the Hubble Space Telescope.It is designed to document the first third of galactic evolution, fromredshift z ~ 8 to z ~ 1.5. It will image more than 250,000 distantgalaxies using three separate cameras on board HST from the mid-UV tonear-IR, and it will find and measure Type Ia SNe beyond z > 1.5 andtest their accuracy as standard candles for cosmology. Five premiersky regions are selected, all with extensive multi-wavelength imagingand spectroscopy from X-ray to radio.

The heart of CANDELS is the WFC3/IR camera, which opens up extensivehigh-resolution near-IR imaging on Hubble for the first time.WFC3/IR's longer wavelengths reveal the true structure of z ~ 2galaxies as outlined by older stars and can find and measure distantType Ia SNe to higher redshifts than previously possible. WFC3/IRreturns superbly accurate YJH photometry that goes 10 times fainterthan ground data, permitting the first complete census of galaxies inthe distant Universe down to a few billion solar masses out to z ~ 8.

The CANDELS special sessions will give an overview of CANDELS andpresent early science results from the first year of data. CANDELS II will focus on more distant galaxies. The number andstellar content of very distant galaxies beyond z ~ 6 will bedescribed, along with the structure of distant AGN hosts and earlyblack-hole growth rates. A summary of data on distant supernovae fromboth the CANDELS and CLASH programs will be provided. CANDELS alsohas a very active program of theoretical mock catalogs and galaxysimulations that are being released for use by the astronomicalcommunity, and these also will be described.

419.01 – **CANDELS Results on High-Redshift AGN and Early Black Hole Growth**

Anton M. Koekemoer[1]

[1]*STScI.*

2:00 PM - 2:13 PM

The CANDELS survey provides a unique probe of AGN evolution to very early epochs, through a combination of deep HST optical+YJH imaging over both GOODS fields as well as AEGIS, COSMOS, and the UDS. The rich multi-wavelength datasets on these fields include extensive coverage from Chandra, XMM, Spitzer, Herschel, and other facilities, which can be combined to yield robust constraints on the properties of faint, high-redshift AGN. These enable evolutionary models of black hole growth to be examined in the context of early galaxy formation, in particular determining the faint-end slope of the high-redshift AGN luminosity function in order to obtain constraints on the black hole mass function and the accretion history at these early epochs. Initial results from the CANDELS survey on the properties of high-redshift AGN and early black hole growth will be presented, as well as the outlook for the parameter space probed once the survey is complete.

419.02 – **Supernovae at *z*>1.5 from HST**

A. G. Riess[1], **Steven A. Rodney**[2]

[1]*STScI,* [2]*Johns Hopkins University.*

2:15 PM - 2:28 PM

Future measurements of dark energy from growing samples of high-redshift type Ia supernovae will require an advancement in our understanding of their foundation as indicators of distance. Specifically, we seek to understand the nature of their progenitor systems and the related degree of their evolution as distance indicators.

We are undertaking a three year program to harvest the highest redshift SNe Ia ever observed---perhaps among the very first SNe

Ia in the Universe---found in two Hubble Space Telescope Multi-cycle Treasury programs, CANDELS and CLASH. By acquiring follow-up observations of SNe Ia at $1.5<z<2.5$, SNe Ia which are truly young, we will obtain: (1) a direct, explosion-model-independent measure of the evolution of SNe Ia as distance indicators, insensitive to the unknown nature of dark energy (2) the first measurement of the SN~Ia rate at z~2 to distinguish between prompt and delayed SN Ia production and their

corresponding progenitor models. Without a complete theoretical model of type Ia supernovae in sight, the highest redshift SNe Ia provide the only direct, empirical evidence to constrain evolution in their lower-redshift brethren--those on which dark energy measurements rely. This program is now under way and I will review progress including the first few discoveries.

419.03 – **Probing Galaxy Evolution from z = 4 - 8 with CANDELS**

Steven L. Finkelstein[1], C. Papovich[2], B. Salmon[2], M. Giavalisco[3], N. Reddy[4], H. Ferguson[5], M. Dickinson[6], A. Koekemoer[5]

[1]*University of Texas at Austin,* [2]*Texas A&M University,* [3]*University of Massachusetts Amherst,* [4]*University of California, Riverside,* [5]*Space Telescope Science Institute,* [6]*National Optical Astronomy Observatory.*

2:30 PM - 2:43 PM

The rest-frame ultraviolet (UV) color is one of the most accessible diagnostics of galaxy properties at high redshift. Here we present an analysis of the evolution of the rest-UV colors of galaxies in the epoch $4 < z < 8$. We use the new deep and wide data available in the GOODS-S field from the CANDELS Hubble Space Telescope Multi-Cycle Treasury program, as well as existing data in the HUDF and ERS fields to select galaxies via photometric redshifts. Our sample consists of ~2800 galaxies, with > 110 galaxies at $z = 7 - 8$. We parameterize the rest-UV color via the UV spectral slope β, which we measure while performing spectral energy distribution fitting, measuring the slope of the best-fit model spectrum in the defined wavelength windows. We use simulations to show that this new method results in a smaller average scatter on β than when using solely a single color. We find that the typical UV spectral slope evolves significantly from -1.8 at $z = 4$ to -2.3 at $z = 7$. This evolution of β with redshift can be explained by an increase in dust extinction in a typical galaxy in our sample, from very little at $z = 7$, to $A_V \sim 0.4$ mag at $z = 4$, possibly due to an increasing dust contribution from low-mass ($< 3\ M\odot$) AGB stars at $z < 7$. Finally, we find that $\beta = -2.6 +/- 0.3$ for faint ($L < 0.25\ L^*$) galaxies at $z = 7$. This redder value than previous claims in the literature, along with the reduced error bar due to the deeper data and new measurement method, casts further doubt upon the existence of “exotic” stellar populations in these galaxies.

419.04 – **A First CANDELS Census of Luminous Galaxies at z > 6**

Haojing Yan[1]

[1]*CCAPP, Ohio State University.*

2:45 PM - 2:58 PM

The "Wide" component of the CANDELS program provides us an unique opportunity to search for the most luminous galaxies at z~7 and to characterize the star formation processes at these very early epochs of the universe. These data, which will eventually

cover ~ 0.2 deg^2 to AB ~ 27 mag in two WFC3 near-IR bands (J and H), are playing a critical role in bridging the gap

between the ultra-deep survey by the HUDF and those wider and shallower surveys from the ground. Here we present our preliminary results at z~7 in the UDS and the

EGS fields, where the "Wide" data have covered ~ 275 $arcmin^2$. About ~ 10 very bright candidate galaxies at z ~ 7 have been found in each field, including two objects that might be gravitationally lensed and one

system that shows a strong indication of merging. The number density of such very bright candidates could suggest that the bright-end of galaxy luminosity function might have a different evolution trend in early time as compared to the faint-end.

419.05 – **CANDELS Theory: Predictions and Model Constraints**

Risa H. Wechsler[1]

[1]*Stanford Univeristy.*

3:00 PM - 3:13 PM

CANDELS data is measuring the number densities, stellar masses, star formation rates, shapes, merger rates, and clustering properties of galaxies from z ~ 8 to the present. I will describe the constraints already achieved and expected from these data on the empirical connection between dark matter halos and the galaxies that host them, as well as on the physical properties of galaxy formation from cosmic dawn (z~6-8) to cosmic high noon (z~1-3). The talk will highlight the current activities of CANDELS theorists, including new semi-analytic and semi-empirical models based on high resolution n-body simulations and constrained with CANDELS data.

419.06 – **CANDELS Theory: Zoom-in Cosmological Hydrodynamical Simulations of Galaxy Formation**

Piero Madau[1]

[1]*University of California.*

3:15 PM - 3:28 PM

Zoom-in cosmological hydrodynamic simulations in a LCDM Universe are beginning to provide detailed insight into the

processes of baryonic acquisition and disk formation in massive galaxies. Artificial images, generated to

correctly compare simulations with observations, are providing new clues to galaxy assembly and a unique theoretical

support for the CANDELS Treasury Survey.

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420 – AIP Gemant Award: Tycho to Kepler: Four Centuries and More of Astronomy and the Media

Invited Session – Ballroom D – Thursday, January 12, 2012, 3:40 PM - 4:30 PM

420.01 – **Tycho to Kepler: Four Centuries and More of Astronomy and the Media**

Stephen P. Maran[1]

[1]*American Astronomical Society.*

3:40 PM - 4:30 PM

From Tycho Brahe’s printing press in 1584 to the Kepler Mission corn maze of September 2011, astronomers have indulged in a wide range of sometimes-novel methods to get the news out. The results have often edified (or irritated) colleagues and excited and occasionally, educated the public. The objectives have been to claim credit, show progress to funding entities, save endangered programs, and share the excitement of astronomical discovery.

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421 – Berkeley Prize: Mapping the Fuel for Star Formation in Early Universe Galaxies

Invited Session – Ballroom D – Thursday, January 12, 2012, 4:30 PM - 5:20 PM

421.01 – **Berkeley Prize: Mapping the Fuel for Star Formation in Early Universe Galaxies**

Linda Tacconi[1]

[1]*MPI Fur Extraterr. Physik, Germany.*

4:30 PM - 5:20 PM

Stars form from cold molecular interstellar gas, which is relatively rare in galaxies like the Milky Way, which form only a few new stars per year. Massive galaxies in the distant universe formed stars much more rapidly. Was star formation more efficient in the past, and/or were early galaxies richer in molecular gas? The answer was elusive when our instruments could probe molecules only in the most luminous and rare objects such as mergers and quasars. But a new survey of molecular gas in typical massive star-forming galaxies at redshifts from about 1.2 to 2.3 (corresponding to when the universe was 24% to 40% of its current age) reveals that distant star-forming galaxies were indeed molecular-gas rich and that the star-formation efficiency is not strongly dependent on cosmic epoch.
